

THE DEVELOPMENT OF BRITISH SURGERY IN THE HOSPITALS ON THE LINES OF COMMUNICATION IN FRANCE.

BY

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The general hospitals on the lines of communication in France have undergone a steady process of extension in accommodation and development since August, 1914. They have been housed very variously—some in the original tent units, some in huts, and some in large buildings adapted to their present purpose. Tented units under the climatic conditions of France have proved to possess but one virtue, that of mobility, and in all the tented hospitals still remaining a certain proportion of huts for serious cases, operating theatres, mess accommodation and stores and offices, have been added. The most satisfactory units are huted throughout, and these leave little to be desired either for comfort or for satisfactory work, even when compared with the civil hospitals at home. Most of the buildings now in use are either of the nature of public buildings or of large hotels. Each possesses some special advantages. The large rooms of casinos, etc., form excellent wards, easily overlooked and economical to work, but such buildings need usually considerable reinforcement with regard to sanitary accommodation. The hotels are more convenient for officers as providing a large number of smaller rooms, but this necessitates a somewhat larger nursing staff, and renders attention to individual patients a more troublesome task.

Special hospitals are set apart for the treatment of infectious cases, for skin diseases, and for venereal cases.

All the Dominions are represented. Thus Canada, Australia, New Zealand, and South Africa have all provided general or stationary hospitals in addition to the more mobile units present in the advanced lines. There is also an American voluntary unit.

Each unit is complete in itself, possessing operating theatres, clinical laboratory, and its own disinfecting apparatus. The only department that is commonly massed when a number of units are collected in the same area is the mortuary and accommodation for *post-mortem* examinations. The majority of the units—the normal capacity of which is 520 beds—have been extended by the provision of additional ward accommodation to receive 1,040 patients, while in times of stress a further extension to 2,000 is possible by the addition of tents. The number of patients which may need to be dealt with during active fighting may be very large; thus during the first three months of the action on the Somme as many as 8,500 wounded men have been passed through a single unit. This necessitates ample operating theatre accommodation, and in all either a large theatre is provided, or in one type of unit two, so that at least four operating tables can be kept at work contemporaneously. In spite of these provisions, at busy times the surgeons may be engaged continuously in shifts for two or three days and nights without cessation.

Within certain limits, arrangements exist for the aggregation of special classes of injury, such as fractures of the bones of the limbs, injuries to the face and jaws, compound and complicated fractures of the skull and vertebral column, and wounds of the chest.

In connexion with each large hospital camp convalescent camps are established, and life in these is rendered more pleasant to the men by the provision of the social huts of the Young Men's Christian Association, the Church Army, and other bodies.

HOSPITAL TRAINS AND MOTOR AMBULANCES.

The vast majority of the patients admitted to the general hospitals are brought down by the hospital trains. Although even the best of the present trains can only be said to be a slight advance on some of those in use during the South African campaign, or those already provided for transporting the patients on their arrival in port in England at the commencement of this war, yet the development of the hospital train in France was a matter of extreme urgency and great difficulty in the initial stages of this campaign. It seems as if both France and Germany had relied for the railway transport of the wounded on the same means which served the purpose in the war of 1870-71. In fact, with the exception of the addition of frames for carrying stretchers placed on the floors

of merchandise wagons, no special arrangements appear to have been made. The trains conveying the wounded from the front were provided with no permanent arrangements for cooking food, no sanitary conveniences, no provision for the carriage of water, and, in fact, consisted of a mere string of trucks, with no means of intercommunication to allow the attendants to pass readily from wagon to wagon. To add to the miseries of the journeys made in these trains, they were long, sometimes extending over two or three days before the west coast was reached.

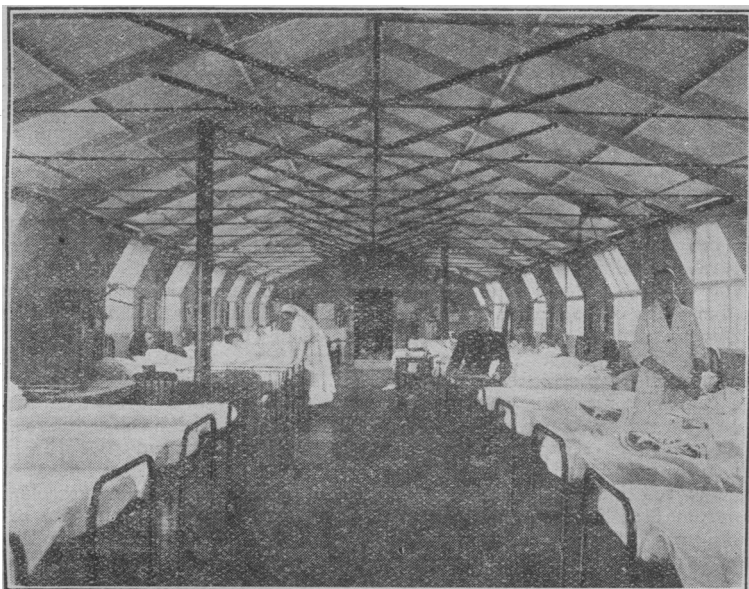


FIG. 1.—Interior of a ward at a general hospital at a base in France.

A small difference in gauge in the French and English lines prevented the prompt shifting of English hospital carriages across the Channel, and too great praise cannot be accorded to the officers who set to work to improvise more satisfactory means of railway transport. Odd carriages of every build and description were obtained whenever opportunity offered, and within a few weeks with alterations hastily but effectively carried out, a number of efficient if not luxuriously appointed hospital trains were forthcoming, and it says much for the officers who did this work that although at the present time over thirty hospital trains are running, no less than seven are of the original improvised series, and are still found efficient.

One word should be added regarding the fleet of improvised barges which run on the canals between the front and two of the general hospital areas. There is no doubt that the smooth passage of these boats provides the acme of comfort for patients to whom the unavoidable shaking of a railway journey entails both pain and harm. It is unfortunate that the general utility of the barges is limited to the few districts in which canals are to be found.

The splendid motor ambulance convoys attached to each district, and for most of which the army is indebted to the Red Cross Societies of the United Kingdom and the Colonies, have been already referred to as to their work at the front, and no further mention of their devoted work is necessary at this place.

As to the last link between the general hospitals on the lines of communication and the base in England, the hospital ships, it suffices to say that they leave nothing to be desired.

WOUND TREATMENT.

This question, which has exercised the ingenuity of man since the birth of surgery, has abated no jot of its capacity for arousing controversy and avoiding a solution which can satisfy all.

Experience has in no way controverted that gained in civil practice in the use of aseptic methods, but has, on the other hand, proved conclusively that advance in the treatment of septic wounds has had in this campaign to start from an unfamiliar standpoint, and has progressed but slowly. Practical application has demonstrated the superiority of the Listerian principle and method, but the multiplicity of the chemical media employed affords evidence enough of the difficulty met with in establishing any one means as that suitable for every class of case. On two points alone can no difference of opinion exist: (1) The urgency of an efficient primary mechanical cleansing and exposure of the wound cavity, and (2) the importance of maintaining the wounded part at rest. The latter point raises the first great difficulty which has to be met by the military surgeon, the absolute necessity of early transport of the wounded man; and leads directly to a second, the amount of interference advisable in wounds which have reached the "intermediate stage," that is, the period of established infection during its first phase, the condition, in fact, in which a large proportion of all gunshot wounds reach the general hospitals on the lines of communication.

Speaking generally, it has been shown that if the primary mechanical cleansing of the wound has been thoroughly carried out, no further gross intervention should be necessary; further, that if want of time and medical officers has not allowed of this procedure being fully carried out, yet if the wound has been sufficiently opened up and primary drainage ensured, the subsequent treatment is comparatively simple. From the point of view of the surgeon on the lines of communication, free incisions are never objectionable, provided they be made in such directions as not to render the subsequent secondary closure of the wound impracticable, the one structure for which he pleads avariciously being the integument. The primary cleansing, given satisfactory surroundings, cannot have been undertaken too early, as every hour of delay adds to the subsequent task of dealing with the infection. In this relation the immediate removal of shell fragments and clothing is of the first importance, because if allowed to remain the deferred operation, even in minor wounds, may prove a procedure of great danger when the patient has arrived at the general hospital on the lines of communication. Such an apparently trivial operation may be followed at this stage by an acute extension of anaërobic infection involving the whole segment of a limb, the entire member, or indeed be sufficiently extensive to lead to the loss of the limb, or even the patient's life.

The conditions of war, however, not infrequently prevent an ideal early treatment of the wounds. It may be impossible to remove patients from "No Man's Land," or even from the trenches, for many hours or even days after reception of the wound. On the occasion of serious fighting the number of the wounded may make it impossible for the requisite amount of time to be spent on individuals, especially those less seriously injured. Lastly, unavoidable delay in transport may result in extension of infection and conversion of a promising case as it left the casualty clearing station into one arriving at the general hospital in a highly unsatisfactory condition.

Happily, whatever the initial procedure and application may have been, in many cases the young and healthy patients arrive in good general condition, the local wound progressing satisfactorily, in some instances devoid of any serious infection. In a considerable proportion, however, men are admitted suffering, both generally and locally, with every grade of infection from the slight to the most severe. The former class present little difficulty, the wounds heal readily under any form of simple application, or, as a time-saving and precautionary measure, the smaller wounds may be completely excised and the gap sutured. The latter method, especially advocated by Colonel

H. M. W. Gray, has been attended by success in his own hands and in those of other surgeons, particularly in the case of uncomplicated scalp wounds or the smaller multiple injuries inflicted by fragments of shells or bombs.

A vastly more difficult problem is presented by patients arriving in the stage of acute development of infections. The wound has already been primarily opened up and cleansed, and the question arises whether further surgical interference will effect improvement or lead to increased extension of the infective process. On the one hand, it is evident that the patient is suffering from an exacerbation directly due to the disturbance involved by transport; on the other, the possibility is always present that delay, even of a few hours, may allow such progress as to render any further intervention useless. A rough-and-ready distinction between cases in which clinical evidence suggests anaërobic or aerobic infection respectively to predominate forms the most useful guide. In the former case delay may be fatal to life or limb, in the latter an interval of rest often results in a rapid subsidence both of local signs and general symptoms, and no further incision may be required.

Patients arriving at the general hospitals may have been submitted to several varieties of primary wound treatment. Speaking generally, the principles adopted have consisted in the maintenance of rest, moisture, and an antiseptic application. In the earlier stages of the campaign numerous antiseptic solutions were employed, also the hypertonic saline solution, but of late, in the great majority of cases, solutions of which the active constituent is chlorine have found most favour and have proved the most satisfactory in practice. Eusol, and with gradually increasing frequency the Dakin-Daufresne solution of hypochlorite of sodium, are those now most commonly resorted to. In the case of the former, moist gauze dressings, in combination with ordinary rubber drainage tubes, have been generally employed; for the latter the technique of Carrel is used.

A smaller number of cases have been treated by other methods, such as primary suture, the salt pack, closure after the introduction of a mixture of iodoform, bismuth subnitrate and paraffin (Rutherford Morison's method), a solution of brilliant green, etc. A word may be added regarding the salt pack method advocated by Colonel H. M. W. Gray. This method, consisting in a thorough packing of every crevice of the wound with gauze, between the layers of which tablets of sodium chloride are enclosed, is suitable for wounds of the large funnel type or of a superficial nature. It is not safe for tunnel wounds, wounds implicating the large vessels, or highly comminuted fractures. The early action of the sodium chloride is inhibitory, and gives no aid to the healing process; indeed, the tablets, even when enveloped in gauze, cause local necrosis of the tissues opposite to them. On the other hand, wounds dressed in this manner may be left untouched in many cases for a week or ten days, during which period the patient's general condition remains excellent. The pack, acting as a foreign body, excites a local reaction around the wound, with a consequent narrow wall of inflammatory infiltration which protects the general system from the absorption of toxic products from the wound. Suitable cases dressed in this manner arrive in a surprisingly good condition at the general hospitals, and the wounds do well with subsequent cleanly antiseptic treatment. Subsequent introductions of the pack are neither conducive to rapid closure of the wound, cleanliness, nor the amenities of the ward, and are undesirable.

It may be well here to mention the experience which has been gained as to three points in the technique of the treatment of septic wounds—drainage, irrigation, and baths.

Drainage.

The methods of maintaining the free escape of septic discharges from the wound have undergone considerable modification, although no doubt has arisen as to the cardinal importance of the principle to be carried out. In the earlier stages of the war it was effected mainly by the introduction of rubber tubes of large calibre and other devices, and these were retained for prolonged periods at the general hospitals. The objections to this method—the tendency of the tube to form for itself a localized channel useless for general escape of fluid, the presence of a foreign body in the wound capable of exercising injurious local

pressure, the establishment of a track by which infection could be freely conveyed from the surface to the depths of the wound cavity, and lastly, the difficulty of determining the moment at which the tube might be safely removed after its prolonged stay—were obvious, but they were faced for a time in view of the very serious infections that had to be dealt with. A revulsion, however, soon followed, in consequence of the unsatisfactory results attained, and the tube is now retained as a provisional measure, and in many cases not employed at all. The main element in the decreased use of the cylindrical tube has been the introduction of what may be called the "curtain" method. This is well illustrated in two forms by Carrel's and Rutherford Morison's systems respectively. In Carrel's the wound surfaces are kept apart not by the small tubes employed for the purpose of instillation, but by the layer of fluid constantly renewed between them and the light gauze packing introduced to retain it. In Rutherford Morison's, a thin layer of an antiseptic medium covers every part of the surface of the exposed tissues, and forms a curtain or cleft which allows for the escape of such fluids as may collect within the wound. The drainage effected by the salt pack is of a similar character, supplemented by the absorptive power of the pack itself before it becomes thoroughly impregnated with the discharges.

Irrigation.

Continuous irrigation has greatly lost in favour; it has the primary objection of inconvenience to the patient, while experience has demonstrated the difficulty of preventing the fluid from forming definite runlets, and consequently of ensuring the flow of the fluid employed over the whole surface of the wound. Its use has consequently been more and more restricted; and, except in the form of a periodical flush, irrigation is little employed.

Baths.

Antiseptic baths have also lost in favour with the development of more effective antiseptic methods. Beyond the obvious difficulties of so arranging the limb as to avoid pressure and swelling (a difficulty, by the way, much diminished by the excellent form of bath devised by Captain M. Donaldson), the bath entails the serious disadvantage, in dealing with a septic limb, of the impracticability of preventing hurtful movements of the part.

At the present time the most successful results that are being attained in all forms of wound are undoubtedly those in which the Carrel-Dakin method is employed. This method has not only shown itself successful in the early treatment, but also in the later treatment of septic wounds, even in the stage of chronic established suppuration. It has been definitely proved that simple flesh wounds dealt with during the first twelve hours after infliction can be rendered practically sterile in an average of six days, those dealt with later in an average of twelve days, that compound fractures may be sterilized within three weeks, and that all three classes of case may be secondarily sutured and closed at these dates. Economy in time, diminution in the risks of secondary complications, increase in the comfort and well-being of the patient during treatment, are all ensured by the method.

It also ensures what has become the supreme object in dealing with septic wounds, the possibility of early secondary suture. The importance of using a bacteriological test to determine the date of closure of the wound cannot be too strongly impressed if anything like habitual success is to be attained. Opportunity has not yet been afforded for the trial of the method during a great rush of wounded men, but arrangements have been made to carry it out if possible. Even should this prove impracticable, the system can readily be carried out in quieter times for a very large number of patients. It has one obvious advantage over any other method of treating septic wounds, the production of a thin supple scar, not likely to interfere with the mobility of the parts, or to cause trouble by subsequent contraction.

The alternative method of secondary closure (that of Rutherford Morison¹) avoids the tedious process and careful manipulation essential to the success of Carrel's method, saves much time on the part of both surgeons and nurses, and the patient has not to undergo the discomfort of repeated dressings. Little experience has yet been gained

of its suitability as a primary procedure, but in infected suppurating wounds it has attained great success. It must, however, be allowed that the cicatrix obtained is very inferior to that which follows the use of Carrel's system, from the initial period onward, and the inclusion of particles of bismuth and iodoform has some disadvantages, both immediate and remote. One great advantage of Rutherford Morison's method is also lost in the cases treated by it in a field ambulance or casualty clearing station—the patients must undergo transport with its consequent shaking and disturbance of the wound; hence patients with the slighter injuries, whose wounds have been closed by this method often arrive with the composition escaping from a wound in which little or no union has taken place, and no appreciable benefit has been conferred.

While it may be said fairly that the Listerian principle has been more nearly attained by the method of Carrel than by any other in use, and that the results are of a very satisfactory nature, yet it must still be allowed that an ideal antiseptic medium remains to be found, especially in respect of consistency of strength and persistence in action. In both respects the bismuth iodoform methods offer some advantages to make up for the cruder character of the cosmetic results obtained. In France the surgeon, like the modern Jew, still awaits the advent of the Messiah; perhaps that advent is near in the person of flavine. Meanwhile, we rest in hope and happy in the firm belief that "the stimulus of imperfection taking place immediately calls forth the action of restoration," and the struggle is maintained to further the great principle, "the first and great requisite for the restoration of wounded parts is rest, as it allows that action which is necessary for repair to go on without interruption," a struggle which only the military surgeon on active service can fully appreciate.

SECONDARY HAEMORRHAGE.

In the light of modern surgery this accident has been deplorably common, and though but little new has emerged from the experience of the war, a few remarks upon the subject seem warranted, the more so in that the increasing frequency with which transfusion of whole blood has been employed to counteract the effects of the accident does show some advance in treatment.

As a manifestation of septic infection, it is obvious that improved methods of wound treatment offer the best chance of reducing the frequency of secondary haemorrhage, and it may be confidently stated that with the development of more satisfactory methods the accident has become less common. Still it must be recognized that in dealing with gunshot wounds we are likely to be of necessity limited to the process of secondary sterilization of an infected wound; further, that we stand in the face of a variety of wound in which incomplete primary lesions of the blood vessels are more common than in any other. The eventual perforation of the vessel wall, therefore, is up to a certain date more commonly the result of the separation of a slough of primarily devitalized tissue than due to the extension of a process of ulceration from without.

One or two special features may be emphasized in connexion with secondary haemorrhage from gunshot wounds. It may, of course, occur from any large vessel, or in old toxæmic or septicæmic subjects it may be of the parenchymatous variety. Given this generalization, however, we find that certain vessels are much more commonly the source of bleeding than others. The localization is determined by the degree of fixation of the vessel and the firmness of the bed upon which it lies. Thus the circumflex branches of the axillary artery, the subscapular or posterior scapular vessels in proximity to the scapula, the gluteal artery, the articular branches of the popliteal artery, the circumflex branches of the profunda femoris, the femoral artery in the lower part of Hunter's canal, and the anterior tibial artery as it lies on the interosseous membrane, are all common sites, and, it may be also remarked, troublesome ones in which to deal comfortably with the injured vessel. Another peculiarity is the comparative frequency with which large trunks in mobile positions, such as Scarpa's triangle, may escape damage by displacement and lie exposed on the surface of a large open wound. Such vessels may not infrequently have suffered contusion with consequent thrombosis.

As to the general treatment of these injured vessels,

little new has been evolved; direct local ligature, prolonged forcipressure, or at the last extremity local plugging, are still the means on which the surgeon must depend. On rare occasions, as an emergency measure, a proximal ligature may be applied, but this is rarely successful and often harmful. A single exception to this rule must be allowed in the case of uncontrollable haemorrhage from wounds of the gluteal region; here in several instances ligature of either the internal iliac artery or its posterior trunk has proved a successful measure.

The proper method of treatment of an exposed arterial trunk, whether thrombosed or not, has opened up a question upon which the civil surgeon rarely has to form a decision. It may be broadly stated that the line of treatment depends mainly upon the degree of septicity of the wound of the surrounding soft parts. If the arterial coats are not seriously damaged and the wound be in a condition likely to respond to antiseptic treatment, an expectant attitude should be assumed if the vessel be pervious. If, on the other hand, the artery is thrombosed, the right course is to place ligatures both above and below the obliterated portion of the vessel, because such arterial thrombi in any case result in permanent occlusion, while in many instances the vessel may give way at the limits of the clot, a solid cylinder, like a pencil, coming away with great risk of haemorrhage; beyond this the clot provides a possible source of a peripheral embolus.

As to the general treatment of patients in whom a secondary haemorrhage has occurred, internal styptics such as calcium lactate have proved useless. This is easily intelligible in the case of the larger vessels, for in such a more or less rounded opening is usually present, the occlusion of which by a mural clot is of no more than very temporary use, while a local thrombus obstructing the whole lumen is unlikely to form. Even in cases of the parenchymatous variety internal remedies have proved useless.

The main advance in treatment has consisted in a return to the practice of transfusion of "whole blood," which has in great measure displaced the unsatisfactory saline infusion. For the popularization of this method we are mainly indebted to our Canadian colleagues in France. Several methods have been employed—the Kimpton tube, the Unger two-way stopcock, direct connexion of the radial artery of the donor with the vein of the recipient by a paraffin-coated rubber tube provided with silver cannulae at either end, the employment of a series of Record syringes, or the citrated method.

Papers have been written on this subject by E. Archibald,² L. Bruce Robertson,³ A. Fullerton, G. Dreyer, and H. C. Bazett.⁴ The number of cases published is not large; the latter authors include nineteen with eight recoveries. A large number of patients have, however, been treated over the whole army area, and a generally favourable opinion as to the results has been established. It must be remembered also that a very unpromising type of case has often been selected. Generally speaking, the good results have been obtained in cases of pure anaemia; when the anaemia has depended in part on haemorrhage, in part on septic infection, the procedure has not been satisfactory. Again, it has been more frequently successful as a measure in primary than in secondary haemorrhages.

Military conditions have allowed small opportunity for preliminary haemolytic tests applied to either donor or recipient, but, when practicable, a small preliminary transfusion of 10 c.cm. of the donor's blood has been made the day previous to the main procedure; accidents due to haemolytic reaction have not, however, been common. In one case, under the observation of the writer, the patient passed highly blood-stained urine for the succeeding thirty-six hours, but he recovered with no further bad symptom. In a few others alarming symptoms have passed off with no further result when the transfusion was discontinued, and two patients have probably died as a direct result of the treatment. Ill effects have not been sufficiently numerous, however, to raise the question of justifiability in the desperate cases for which the procedure is undertaken.

GAS GANGRENE.

This complication has been already dealt with, as it is met with in the field ambulances and casualty clearing stations. Naturally the most acute cases do not reach the hospitals on the lines of communication, and of late,

coincidentally with the development of the clearing station accommodation and the general acceleration of the transport of patients consequent on a shorter and quicker journey, fewer cases of the most serious nature arrive. None the less, the insidious manner in which the process starts, the rapidity with which it spreads, and the tendency which exists for delay in its development, all tend to maintain a constant supply of cases to the general hospitals.

Some early conceptions of the disease have undergone considerable modification; thus it was assumed, in consequence of the frequency with which the limbs are attacked and the fact that extension from the limbs to the trunk is commonly confined to the subcutaneous tissues, that the trunk itself was seldom primarily affected. More extensive observation has shown the fallacy of that assumption, and it is now well known that the contents of the cranial cavity, the pleurae, the pericardium, the peritoneum, the retroperitoneal tissue, and the muscular planes of the trunk are all attacked with varying degrees of frequency. The implication of the great body cavities, however, offers some special features; thus the infection is usually primarily of effused blood or blood clot, and in consequence of the resistance of freshly effused blood to the growth of the organisms, the exacerbation of symptoms is, as a rule, retarded for several days, or even a longer period. The symptoms in such cases offer a remarkable resemblance to those of a sudden internal secondary haemorrhage, a fact that in early days sometimes led to confusion.

Another question which is at present undetermined is the relative frequency with which patients die from a pure toxæmia, or of an actual septicaemia. The number of instances in which organisms have been observed in or cultured from the blood is relatively few, a remarkable fact considering the rapidity with which the entire vascular system is invaded after death. Certain observations, however, beyond those made upon the blood afford definite evidence that at an early stage a general infection is not uncommon. It was remarked at Boulogne in an early stage of the campaign that certain patients arriving with gaseous cellulitis of the limbs had at the same time local patches upon the trunk or arms at the sites of previous punctures for the injection of tetanus antitoxin, or even morphine injections; further, that similar phenomena might follow the introduction of a saline infusion. Again, cases were observed in which gas was voided with the urine, and in one of these a culture of *B. perfringens* was made from the urine. Further, a less striking occurrence, as the tendency of these infections to cause local thrombosis is well known, a certain proportion of the patients developed metastatic deposits in other parts of the body. It may be observed that one of the most common seats of these latter, the opposite buttock, is not always free from the suspicion of being a direct extension.

In other cases the rapidity of the process suggested a pure toxæmia, and some support to this view is found in the rapidity with which the limbs in some cases enlarge from a toxic oedema independently of the presence of gas. Major Rowland found that the filtered fluid from such cases caused general oedema and death in a few hours when injected into rabbits or guinea-pigs independently of the presence of any organisms, and was working on this subject at the time of his death.

The factors determining the mode and rapidity of extension of the process have also given rise to much interest. Certain facts appear to definitely favour the view that the process is a true cellulitis, although the frequency and extent to which the muscles suffer has led some observers to speak of the anaerobes giving rise to the condition as muscle feeders. It may be premised that the organisms concerned can establish no footing in the body in the absence of either dead tissue or some foreign body, and, this fact granted, it is obvious that the localization of the dead matter will correspond with the commencement of the process. Since the establishment of the fact by Major Curtis Webb,⁵ that x-ray examination allows the determination of the presence of gas in the tissues, this method of examination has been widely employed as a means of diagnosis, and the examination of an entire limb by this method (Major Littler Jones) affords some striking information. If, for instance, the quadriceps muscle of the thigh has been wounded, the gas may invade the entire muscle, but the extension will be

seen to follow the course of the great vascular cleft to the leg and even the foot, being localized, in the early stage at least, to the cellular tissue. Again, clinically, the extension of gas from the upper to the lower part of the thigh may sometimes be evidenced by a characteristic elongated swelling following the course of the vessels. Then, with regard to the intimate structure of the muscle itself, the separation of the individual fibres appears to indicate a similar process.

The rapidity with which the cellulitis spreads and destruction is caused appears to depend on the one hand on the tension in the special area affected, and possibly on the virulence of the organism or group of organisms concerned; on the other, on the degree of interference with the vascular supply either by the original damage or by subsequent thrombosis of the vessels concerned. Captain Bashford⁶ has dealt with both these questions. The clinical observation of the rapid development of massive gangrene in a limb subsequently to the ligature of the main artery, or again the rapid death of that part of a long muscle cut off from its arterial supply, is common enough.

As to the actual organisms or combination of organisms responsible for the gangrene in its special forms, which may determine either the soft oedematous limb or the tight drum-like, or the emphysematous varieties, no definite knowledge exists. Captain Henry has furnished a short summary (printed at page 806) of the important series of observations carried out by himself⁷ on the organisms concerned.

Another point of interest in this relation not cleared up is the absence of knowledge as to what determines the rapid haemolysis in one case accompanied by the development of more or less intense jaundice, while other patients present merely the appearance of extreme anaemia before death. Generally speaking, the anaemic patients are those that die most rapidly, and the difference may depend simply on time, since the characteristic brilliant orange-coloured discharge from the wound met with in mixed infections is rarely observed before the third or fourth day. The actual deficiency in the volume of blood in the cases of rapidly fatal issue is indicated by the low tension of the pulse as determined by palpation, and a loud knocking sound in the great arterial trunks, which gains the same intensity as it does in many patients dying from pure haemorrhage, and consequent fall in the diastolic pressure.

Such advance in methods of treatment as has been made rests entirely on the knowledge of the danger of leaving dead infected tissue or foreign bodies in the wound, and the necessity of relieving all tension in the structures affected; thus the knife is still our only aid. In making incisions for the relief of this form of cellulitis it may be remembered that size is of minor subsequent importance, provided the incisions are so planned as to avoid important structures and to allow of subsequent secondary closure. The latter is of special importance since the wounds infected by anaerobes often rapidly clean, and form some of the best for secondary closure at a comparatively early date.

Where amputation is indicated, the one principle to be adhered to consists in the maintenance of an open stump. It has been found that under these conditions, even where the amputation has been made through oedematous tissue, the latter drains freely and no further extension takes place. Beyond this, oedematous connective tissue, especially that of the green variety, is often found to be sterile, hence the inadvisability of interfering with it, particularly around the vessels and nerves, and thus opening up the planes of the limb to further infection.

Sir Almroth Wright,⁸ in a paper on the conditions which govern the growth of the bacillus of gas gangrene in artificial culture media, in the blood fluids *in vitro*, and in the dead and living organism, has made the suggestion that intravenous injections of sodium bicarbonate may prove a means of combating the toxæmia, and gives short details of six patients treated by this method, of whom two survived. He assumes that in the treatment of the so-called "gas gangrene infections of man" he was dealing essentially with the same phenomena as those observed in certain laboratory experiments which showed that the bacillus of Welch, when grown *in vitro* in serum, diminishes the antitryptic power of the medium and

renders it acid, thus converting the serum into a pre-eminently favourable medium for the growth of the bacillus. Experiments on the blood in the dead body showed that it is these chemical changes which furnish the conditions required for the avalanche-like progress of the bacterial infection. Finally, experiments on living animals showed a reduction in the alkalinity of the fluids taken from the focus of infection, and a reduction in that of the circulating blood—also an increase in the antitryptic power of the blood, combined with a diminished or abolished antitryptic power in the infected tissues.

In his investigations of the disease in human subjects he found the same high antitryptic response in the circulating blood and the reduced or abolished antitryptic power in the infected tissues or infected effusions, combined with diminished alkalinity of both tissues and effusions—thus, a local acidosis but also an acidaemia, the latter being found when an infection has culminated in "gas gangrene toxæmia."

TETANUS.

Tetanus, the terrible scourge which gave rise to so great anxiety in the autumn and early winter of 1914, has become a comparatively infrequent wound complication since the adoption of prophylactic injections of antitoxin in all cases of wounds and in cases of "trench foot" accompanied by vesication. Nevertheless cases still occur, in some instances because the primary injection has been given late as a result of the patient not being able to be "collected" from the zone of fire, a few men escape treatment as a consequence of the number of wounded needing to be dealt with after a serious engagement, and special idiosyncrasy may account for others. At an early date it was also recognized that the protective influence of the antitoxin is often exhausted at the end of eight or ten days; hence a general order was given to the effect that the injections should be repeated at intervals of seven days in all cases of serious wound and to patients whose wounds were not progressing well.

The cases met with include every degree and variety of the disease. Thus very acute cases with general spasms, slight cases in which trismus is the main feature, cases of "head tetanus," either of the paralytic class or with clonic spasms of the muscles of mastication, splanchnic tetanus, local tetanus of the limbs, sometimes remaining confined to the wounded member, in others becoming general, and cases of the so-called delayed class. In one remarkable instance of the last variety the patient, who had been sent to England in August with a small wound of the buttock, at the bottom of which was a small retained foreign body, returned to duty two months later. When on duty in the trenches stiffness of the corresponding limb, at first ascribed to sciatica, developed, and later general tetanic symptoms. Active treatment with antitoxin was followed by an uninterrupted recovery.

Accumulated experience has negated the utility of treatment with carbolic acid or magnesium sulphate, both of which remedies were vaunted in the early stages of the campaign. Curative treatment by antitoxin is still upon its trial, and considerable differences of opinion exist both as to its utility and as to which route should be chosen for its exhibition. The subcutaneous route is generally considered unsatisfactory on account of the delay in conveyance of the antitoxin to the required area; hence, although generally chosen for prophylactic purposes, its use as a method of curative treatment is restricted to an auxiliary rôle. The intermuscular route has found more favour, although its efficacy is doubted by many. The intravenous route has not been shown to be specially efficacious, and as accidents of an anaphylactic character have followed its use it has been practically abandoned. The general applicability of the intrathecal route is still under discussion; the chief objection to its use lies in the large quantity of serum which requires to be introduced and the comparatively serious nature of the procedure itself if repeated injections are made. In some cases a definite disturbance of the intracranial pressure appears to result, and in some local inflammatory changes in the spinal theca have occurred. In spite of these objections the intrathecal method has been very largely employed, and a trial is now being made of a highly concentrated antitoxin.

The prognosis has depended in individual cases on the length of the incubation period, and, in spite of treatment,

the mortality has remained above 70 per cent. of all cases treated. Symptomatic treatment by chloral and morphine, particularly the former, has retained its character both in the relief of suffering and as curative, in so far as it tends to delay exhaustion dependent on the spasms.

OTHER WOUND INFECTIONS.

Little new can be said regarding the remaining forms of wound infection, but it may be generally stated that the antiseptic solutions depending upon chlorine for their active element have proved the most successful application. One form of streptococcus infection deserves special mention as possibly corresponding to the variety of "classical hospital gangrene" described as the membranous. Cases of this nature have not been common, although sufficiently so to have become familiar. A wound which has previously been apparently progressing favourably becomes covered with a dense grey tough membrane, firmly adherent to the subjacent granulations. In the earliest stage this membrane does not materially differ from the thin layer of coagulated fibrin and included leucocytes which not uncommonly forms in cases of streptococcal infection which after a time fail to respond to treatment. The same cessation of free discharge from the wound surface is observed, a condition well described by Colonel Sir Almroth Wright as "lymph bound." The membrane then thickens so as to resemble one of the diphtheritic class; in fact strong suspicion was aroused in the earlier stages of the war that the change was due to a diphtheritic infection. Bacteriological examination has, however, in all cases resulted in the discovery of streptococci alone. With the development of the membrane a continuously increasing hard white oedema spreads up the limb or on to the trunk, the patient meanwhile suffering with pronounced signs of toxæmia. Incisions into the oedematous area give rise only to the escape of a small amount of serous discharge, and the tension wounds tend to dry up with little change. Amputation is usually followed by a recurrence of the same type of wound surface, and the patient dies in from four days to a week's time after the commencement of the process. No successful method of dealing with this special form of wound infection has been devised.

SEPTICAEMIA.

The most common form has been in connexion with streptococcal infections. It cannot be said that any advance has been made in the treatment of this condition. Encouraged by the results published by Messrs. Fraser and Bates⁹ in dealing with some acute general infections, and the work of Lorrain Smith and his colleagues, a more or less extended trial has been made of intravenous injections of hypochlorous acid in the form of eusol, but no satisfactory results have been obtained. The same remark obtains to a more limited trial with colloid chloride of gold. The work of Dakin has shown that the antiseptic power of injections of eusol must be small in consequence of the minute amount of the antiseptic in proportion to the volume of the patient's blood. If either this solution or that of chloride of gold can effect any useful purpose, it is probably only by exciting as irritants a certain degree of activity in the endothelial lining of the blood vessels, and in neither case has this proved sufficient to serve the purpose aimed at of sterilizing the blood.

INJURIES TO THE GREAT VESSELS.

The dangerous nature of injuries to the great vascular trunks has been amply demonstrated by the fact that, except one or two injuries to the innominate vessels, the subclavian artery in the thoracic part of its course, and possibly a few iliac (although the writer has seen none of the latter amongst over 300 carefully examined cases of injuries to the larger arteries), injuries to the vessels of the trunk have been conspicuous by their absence on the lines of communication.

A considerable experience has been gained regarding the effects of contusion of the vessels, which has in the main substantiated the French pre-war experimental observations. At the same time, the occurrence of single simple linear fissures of the intima has been a more common form of lesion than one would have been led to

expect. The chief importance of these lesions has been in connexion with secondary hæmorrhage, to which allusion has already been made, and in the frequency with which the injury is followed by thrombosis. Several instances of subsequent embolism have been observed, this particularly in the case of the cervical vessels, where cerebral embolisms are readily detected as a consequence of the obvious signs with which blockage of the cerebral vessels is attended.^{10 11} This experience, combined with that of similar accidents occurring in connexion with actual wounds of the vessels, raises the question of how great a proportion of the instances of gangrene of the extremities following injuries to the vessels of the limbs, either spontaneous or following ligature, is due solely to the local occlusion of the main vessel. It seems likely, if all these cases could be thoroughly investigated, that embolism in the distal circulation plays a more important part than has hitherto been accorded to it, since several observations have been made of its occurrence.

The frequency with which various forms of missile have been employed has been followed by considerable change in the nature of the lesions, the highly contused lateral wound of the artery, and the clean perforation made by the modern bullet, have of late been less in evidence than extensive lateral lacerations and more or less limited lateral perforations caused by fragments of shells or minute fragments derived from bombs. Occlusion of wounds of the vessels by retained shell fragments, the removal of which has been followed by free hæmorrhage, has not been rare. On the other hand, instances of missiles entering and travelling along the blood vessels has rarely been observed. The most striking instances have been those in which shrapnel balls have obtained entrance to the heart or large veins of the trunk and travelled downwards by gravitation. The most interesting feature of these cases, observed also in some wounds of the inferior vena cava, is the moderate degree of primary hæmorrhage which had taken place.

Wounds of the great vessels arrive in the hospitals on the lines of communication usually some days after their infliction, but a considerable proportion may arrive at an earlier date in consequence of the absence of primary hæmorrhage, or the coexistence of some more serious or more easily recognized injury having allowed them to be overlooked. This is especially the case in multiple bomb or shell injuries, where one out of twenty small wounds produced by as many fragments widely distributed over the whole body may have implicated an artery; or in the case of severe fractures of the long bones, accompanied by great swelling of the soft parts.

The result of this experience has been greatly to widen the scope of the stethoscope in the diagnosis of arterial injuries, since auscultation will often reveal the presence of the pathognomonic systolic bruit, when the absence of local pulsation in the swollen area and the presence of pulsation in the distal arterial circulation may, if depended upon alone, lead to a serious error in diagnosis. Further, it has been observed that the local vascular bruits may, in some third of the whole number of injuries to arteries of the lower extremity, and less frequently in other vessels, be conveyed to the cardiac area, and distant vascular lesions have in some cases been detected by the presence of the apparently cardiac murmur.¹² This phenomenon is observed both in pure arterial and arterio-venous injuries. It has also been observed that the distal blood pressure of the limb is materially lowered in the presence of a lateral arterial lesion—in fact, practically to the same degree as if the main vessel has been occluded.

As a consequence of the period at which arterial injuries reach the hospitals on the lines of communication the treatment has been for the most part expectant, the large majority of the patients being evacuated to the base in England. The importance of rest in allowing subsidence of the general circulatory excitement, and the consolidation of the aneurysmal tumour, has been obvious. It is also held that during this period the enlargement of the collateral circulation makes some progress. Some evidence in favour of this view is offered by the fact that the nutrition of the limb is not observed to suffer during this period, while wasting, sometimes of a rapid character, often follows the performance of necessary ligation.

Accidents during this probationary period have not been common: gangrene has been rare; secondary hæmorrhage uncommon, unless the wounds were large and badly

infected; and suppuration of the aneurysm has been an accident of extreme infrequency.

Active treatment has consisted in the main of ligature of the vessels. This has been indicated for extension of the blood effusion within the limb, secondary haemorrhage, signs of pressure on the trunk by increasing size and firmness of the false aneurysmal sac, or signs of inflammation. When the hospital accommodation has allowed a sufficiently long stay a certain number of cases have been operated upon in the absence of any untoward symptoms.

For purely arterial injuries, ligature of the vessel above and below the wounded spot has been the most common operation. In a number of these cases the main vein has been found to be thrombosed, but this accident has not had any adverse influence on the result. The same statement may be made as to the results observed when co-existing wound of the vein has made it obligatory to tie both vein and artery, or in the cases where the main vein had already suffered complete division and occlusion. The same experience has followed ligature of both artery and vein above and below the communicating channel in arterio-venous aneurysms or aneurysmal varices. Hence it has been claimed¹⁸ that simultaneous occlusion of both artery and vein is a negligible occurrence with regard to any increase of risk to the vitality of the limb. Further, that inasmuch as a better balance is maintained between the arterial and venous elements of the collateral circulation, and the blood pressure within the limb increased, the operation is preferable to that confined to the wounded artery alone.

In certain vessels—for example, common carotid, common femoral, popliteal—after ligature of which acute local anaemia and gangrene is specially liable to follow, a limited trial has been made of Tuffier's tubes to maintain temporarily the main current pending the increase of the collateral circulation. In a small series of eight cases (common carotid 1, axillary 1, femoral 2, popliteal 4) in which this method was used, in no instance did gangrene take place. In one femoral case, in which the tibial pulses were absent at the time of operation, feeble pulsation returned and persisted for a few hours, and in the second the foot, which had been cold, at once became warmer and remained so. Such evidence as has been obtained, however, does not suggest that the maintenance of the main current persisted more than a few hours, and the clots expressed from the tubes when removed on the fourth day, although firm in comparison with the terminal projecting into the proximal end of the vessel, did not suggest a very gradual formation. Moreover, in one of the popliteal cases, in which it would have been difficult to place a ligature on the lower end of the artery, it was not found necessary to do so, as the vessel was closed by a firm thrombus. Such experience as has been gained is, however, definitely in favour of a more extended trial of this method.

Suture of the vessels, either end-to-end or lateral, has been employed only in few cases. At the period during which the patients are still in the hospitals on the lines of communication the vessels are still comparatively fixed and difficult to free without damage to the coats, as well as rigid in themselves; hence, if sutures are introduced, the tension upon them is far greater than is the case with normal arteries. Again, a large proportion of the wounds are too extensive for anything but an end-to-end union after removal of the damaged extremities of the vessel, and here again both local tension and an undesirable temporary flexion of the limb to reduce it are opposed to successful suture. Cases, however, do occur in which either form of operation can be carried out. In a small series of six operations the following immediate results were obtained:—Brachial 3: (a) Lateral suture, lumen of vessel reduced more than one-third; no radial pulse before operation, but it returned four days after. (b) Refreshment of ends and end-to-end suture. Radial pulse palpable after operation and persisted. At the end of the third week the distal blood pressure in the limb had risen by 22 mm. of mercury. (c) Excision and end-to-end suture. Radial pulse absent during first two days after operation, then returned. Five days after the operation the distal blood pressure was 30 mm. of mercury greater than before. Popliteal 1: Lateral suture. A good anterior tibial pulse was present the day after operation, but the posterior tibial was absent. Femoral 2: (a) Lateral suture of an arterio-venous communication of six months' standing.

Distal tibial pulses present at the end of the operation and persisted. (b) Lateral suture in Hunter's canal. Tibial pulses absent before operation, but were just palpable four days later. Distal blood pressure still 50 mm. of mercury lower than in other limb.

Time and a considerably more extended observation is needed to determine whether the operation of suture does attain very much better results than simple ligature. The above results, including no sort of accident, seem to do little more than prove that the operation is practicable and not dangerous in selected cases. That a patent lumen is preserved in the vessels in the majority of cases is, however, not yet proved.

In a case of large wound of the thigh, in which the foot was cold and no tibial pulses were palpable, the femoral artery was discovered to be thrombosed 2 in. above the apex of Scarpa's triangle and no pulse could be felt in Hunter's canal. Captain Cowell made an incision one-third of an inch long into the vessel and squeezed out a small decolorized thrombus and a red clot 3 in. in length from the vessel distal to the incision. The vessel was then sutured, and pulsation returned in Hunter's canal but was not palpable at the ankle. A secondary thrombus again formed and obstructed the vessel. It appears probable that if the intima has been sufficiently injured to cause a primary thrombus to develop, operations of this class are not very likely to succeed; still a repetition is probably worthy of trial.

FRACTURES.

At an early stage in the campaign, when wounded men were streaming in large numbers into the improvised hospitals in Boulogne, it became evident that neither the regulation outfit of splints nor the supply of emergency splints manufactured by the mechanics attached to each hospital unit sufficed to cope with the large number of fractures admitted. An opportune paper by Lieutenant-Colonel Robert Jones which appeared about this moment¹⁴ moreover impressed all those concerned in the treatment of these injuries with the enormous advantages offered by splints of the H. O. Thomas class for military use, both in facilitating the early and safe transport of patients, and in allowing efficient extension of the limbs to be continuously maintained. Further, a number of modifications of the type of splints which have subsequently proved of much value were quickly in demand. In order to meet the requirements thus suddenly arising, application was made to the Medical Director-General at the War Office for the supply of a skilled surgical mechanician to undertake the control of a central splint manufactory at Boulogne. Mr. Salmon was sent out, and since that time an enormous number of splints have been manufactured locally, and supplied not only to the general hospitals on the lines of communication, but also to advanced units throughout the army. It would be difficult to overestimate the practical value of this establishment.

The first question which has arisen in connexion with these injuries is the relative importance of the primary treatment of the wound of the soft parts, or the adjustment of the bony fragments themselves. Cases may occur in which either assumes the first place—thus the limb may be threatened by anaerobic infection; reduction of the displacement and maintenance of the bone in position may prove a matter of extreme difficulty as a result of the position and direction of the fracture; or the presence of multiple wounds in inconvenient positions may render it impossible to apply such apparatus as will maintain sufficient extension. Under any of these circumstances treatment of the wounded soft parts may claim priority, but as a general rule the principle of prompt reduction of the displacement and maintenance of extension has been adhered to. It has been recognized that secondary efforts at reduction when a septic wound has cleaned and settled down is a serious operation involving risks of lighting up again a condition which has been with difficulty overcome.

The next question which arises is whether rigid extension in the direct long axis of the limb is to be maintained or the joints placed in the flexed position. For patients treated in France the former method has been the more widely adopted, in order to utilize the facilities in transport which the Thomas's splints undoubtedly offer. As an invariable custom, however, this practice has not been able to be followed, as many surgeons have not been able to obtain good position of the fragments in such

positions as the upper and lower thirds of the femur. To meet this difficulty the Thomas's splints have been bent or other methods employed. For instance, Hodgen's splint for the upper third of the thigh bone, or a swinging frame of the same dimensions of the bed, the feet being fixed by plaster extension strips to the angles of the lower end, and the head and body lowered (Major Sinclair). For the lower third the wire double-inclined plane of Hey Groves has occasionally been employed. All these methods, however, require additional attention and longer stay in France, hence they have not been widely resorted to.

The method of maintaining extension has also been a question much discussed, and fixed extension by a stirrup attached to the end of the Thomas's splints has been commonly adopted. Yet in a large number of cases weight and pulley extension has been preferred and is sometimes necessary. The question, in fact, has not been settled in favour of either of the opposing parties.

A third method, that of a continuous screw, has also been considerably employed, both in conjunction with the type of Thomas's splint with a spat attachment, in the Wallace-Maybury modification of the Thomas, and also in the bent Thomas's splints and their modifications for treating fractures of the humerus with the elbow flexed.

The use of the pin transfixing either the lower end of the femur, or the upper extremity of the tibia, for the attachment of extension apparatus in cases of fracture of the femur, has found little favour in France. This has perhaps mainly depended on unwillingness to make a fresh wound in a limb already the seat of a septic wound; but beyond this, the fact that practically all patients need to be transported at an earlier date than would be convenient for removal of the pin renders the method undesirable.

One great feature in the wards, and an incalculable blessing to the patients and attendants, has been the wide adoption of the overhead rail for the suspension of limbs, and to take the place also of the pulley arranged over the head of the patient's bed in most hospitals to allow him to lift himself by his arms. This was devised at an early date in Boulogne as a result of seeing patients with fractured thigh put up by the so-called Balkan method by Lieut.-Colonel Miles. It has consequently acquired the name of the Balkan support. Two of them, one placed on either side of the bed, may also be employed for the support of an entire hammock bed.

For fixation of the thigh in the abducted position, the abduction frame of Robert Jones was ready to hand, but in the case of the upper extremity much difficulty was experienced in the earlier part of the campaign until the capability of a short Thomas's knee splint for this purpose was fully appreciated.

Captain Page has adopted the ambulatory method of treatment in some cases of fracture of the thigh and the leg, the former with the aid of lateral extending screws fixed above and below to plaster collars surrounding the thigh, the latter by muslin strips impregnated with plaster-of-Paris, after Delbet's method.¹⁵

A great amount of ingenuity has been expended on splints devised to facilitate transport or to meet special emergencies, also on various adjuncts to the splints themselves. Thus many varieties of rubber, metal, or flannel slings to support the limbs in wire splints, extension attachments, forms of glue for fixing extension strips to the limbs, and lastly, the highly efficient counterpoise suspension apparatuses of Major Sinclair

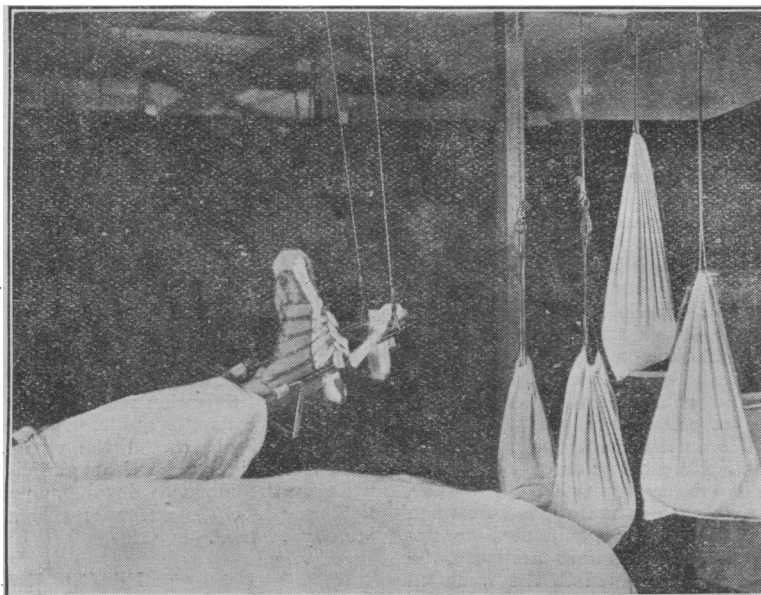


FIG. 2.—The Thomas Splint with Foot Extension, Suspended (Major Sinclair). The foot extension is applied by means of $\frac{3}{4}$ in. strips of flannel bandage, each strip being threaded through two metal triangles. One set of six triangles is aligned along the inner margin, another set of six along the outer margin of the sole. The flannel strips are glued to the sole, sides and dorsum of the foot, care being taken that the ends do not meet over the dorsum. Cotton-wool is dabbed over the glued area to hasten and strengthen the setting. Whilst the glue is drying the Thomas splint is applied in the usual way and fitted with a support to keep heel clear of the bed. The triangles are now threaded with tapes, which are passed over the serrated edges of the special wooden foot-piece and tied. This foot-piece rides on the side bars of the Thomas splint. The foot, now being secured to the foot-piece, is commanded absolutely. It can be flexed, extended, inverted or everted, rotated in or out, lowered or raised. At the same time extension can be applied to the whole limb by tapes attached to the cross-bar of the foot-piece and fixed in the V of the Thomas. Having got length and alignment in the fractured limb, the cross-bar is fixed by tying to the side bars with tape. This is often the only form of extension which can be applied in fractures of both bones of the leg near the ankle. Care should be taken to thoroughly fix the knee in the splint by means of large cotton-wool pads and a bandage. The whole splint is suspended in a C-model suspension.

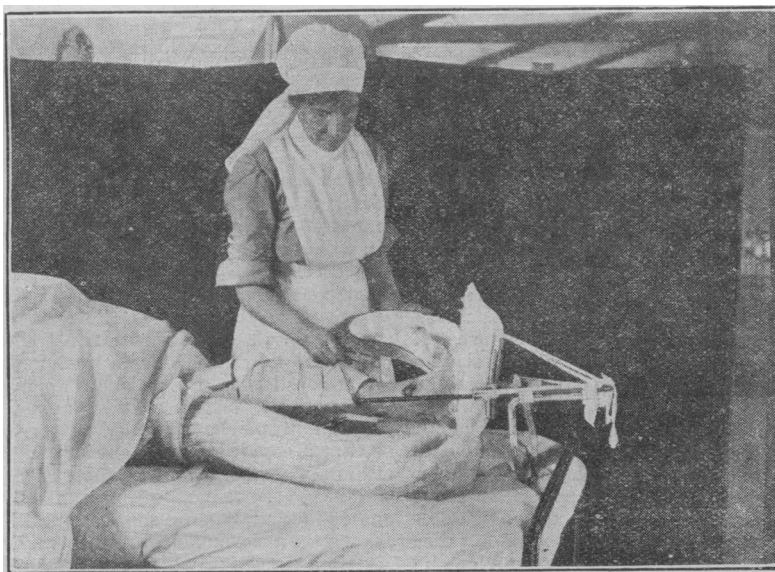


FIG. 3.—Thomas Knee Splint with Plantar Extension (Major Sinclair). A plaster cast is made of the sole of the foot by means of flannel impregnated with plaster-of-Paris. Incorporated in this cast are tapes. When the cast is dry it is glued to the sole of the foot and extension is got by attaching it with the tapes over the serrated border of a special wooden foot-piece.

(Figs. 2, 3, 4, 5). Space does not allow of more than mention of these many adjuncts to convenience, cleanliness, and the comfort of the patients.

Plaster-of-Paris has on the whole been but little used, and mostly for purposes of transport. The difficulty of keeping plaster splints clean has mainly militated against them.

Lastly, as to the treatment of the wounds. In this place it is assumed that proper cleansing, drainage, and removal of loose fragments and foreign bodies has been carried out at the casualty clearing stations. Under these circumstances no further immediate procedures are needed on the lines of communication. Even in the case of inefficient drainage or extending infection great judgement requires to be exercised in interference on the first arrival of the patient.

The object to be aimed at is the secondary closure of the wound at the earliest date practicable, and with this object a continuous antiseptic method should be carried on. Up to the present time the most conspicuous success in this direction has been attained with the Carrel-Dakin method, and if treatment has been commenced at the casualty clearing station, the wound may in a considerable proportion of all cases be closed within a period of three weeks. It may be fairly hoped, in the light of present experience, that the number of chronic suppurating compound fractures will be in the near future largely reduced.

The date at which sequestra should be removed to allow a complete surgical sterilization of the wound has raised some discussion. When the fracture has not been accompanied by sufficient loss of bone for risk of non-union to occur, there can be no doubt that the earliest possible date is desirable. If, on the other hand, little but the periosteum and a few fragments remain, the probability of securing a sufficiently active osteogenesis to effect union is no doubt increased by leaving apparently dead fragments of bone in connexion with the periosteum for some time, because a few bone cells may have escaped to help in repair which will probably perish if exposed in a suppurating wound.

In suppurating fractures of some standing Rutherford

Morison's method of secondary closure after introduction of the iodoform, bismuth, and paraffin compound has been imported from England, and is giving good results.

Radical treatment for the condition of chronic osteomyelitis has not often been undertaken, unless the cases are of such a character as to be subjected to amputation; the majority are transferred to England, where prolonged stay in hospital is more readily assured.

Lastly, methods of mechanical fixation by plates and screws or by wiring have been very little resorted to as primary measures. A very large proportion of the cases so treated failed from the septic character of the wound, but in the face of the results more recently obtained by secondary sterilization and closure of the wound it is probable that these methods may be revived in cases of difficulty of maintaining the frag-

ments in position, or at any rate resorted to at a much earlier date under more favourable conditions.

Both in Boulogne and elsewhere special departments have been established for the treatment of fractures alone, and in the hospitals generally an attempt has been made to collect the patients with fractures under the charge of one medical officer. This plan has obvious advantages

in ensuring special aptitude on the part of the surgeons concerned and the possibility of attaining general results approaching the ideal. At the same time, its general adoption is impracticable; the cases are of a nature to necessitate a long stay in hospital, their collection in one ward imposes a very heavy task on the nursing staff, which needs to be largely increased, and, finally, it not only removes a source of great interest from the general surgeon, but it also renders him less fit to treat such cases when heavy fighting produces them in such great

numbers as to render segregation impossible. It must always be borne in mind that the good military medical officer is a general practitioner, since occasions must always occur with frequency in which he must be prepared to deal efficiently with any kind of casualty. The

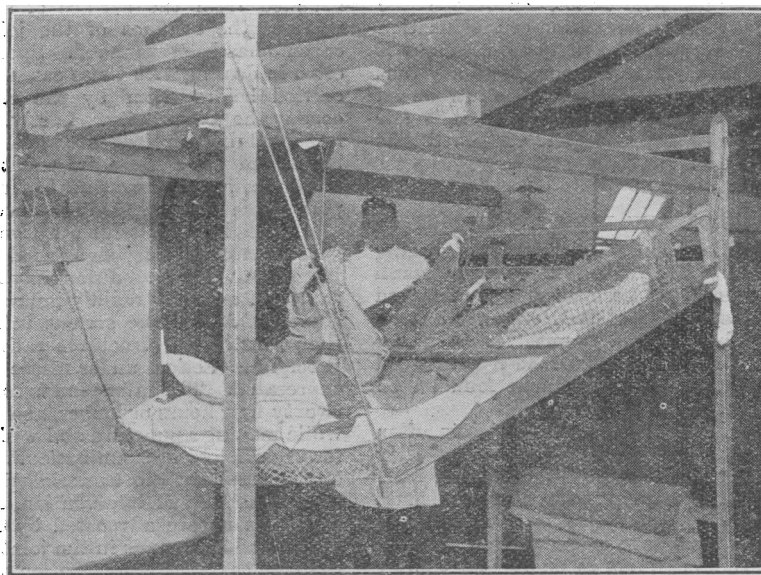


FIG. 4.—The Net Frame used in the Treatment of Fractures of Upper Third of Femur with or without Large Wounds (Major Sinclair). An ingenious combination of the hammock with abduction of the thigh, embodying the principle of Hodgen's thigh splint. A wooden frame 7 ft. by 5 ft. is constructed with a transverse bar, which is at the level of the patient's umbilicus; two leg bars run from the umbilical bar to the foot of the frame. Extensions are applied to both legs by means of gauze and glue. These are passed through holes at the end of the frame and tied. The patient's back and legs are well padded, and the body and legs are supported in the frame by strong one-inch netting. This netting is in three pieces—one for the body, fixed to the sides and head of the frame, and two leg pieces fixed to the leg bars, which are abducted to the necessary angle. Either can be freed independently. The frame is slung by the corners to four uprights (the universal leg suspension frame). Extension is obtained by lowering the head of the frame, usually about 15 inches. This method of treatment is efficient, and the results very satisfactory, both dressing of wounds and nursing of patient being extremely simple.

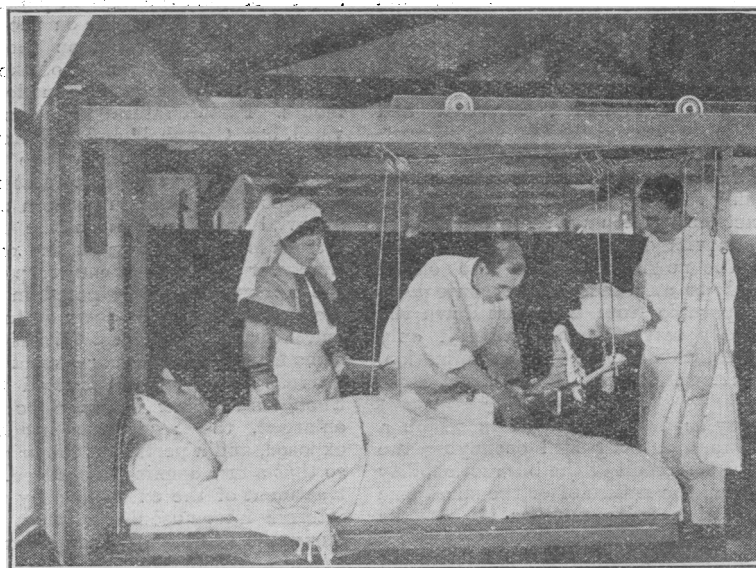


FIG. 5.—Fracture of the Thigh treated with Thomas's Knee-splint and Sinclair's Foot Extension; Counterpoise Suspension from a Travelling Gallery (Sinclair).

only way to carry out usefully this idea is to create one or two special centres in which such cases can be treated as well as possible by specially skilled surgeons, and utilize these as presenting an ideal towards which all should work. Such special hospitals, no doubt, encourage the device of new methods and the perfection or modification of others; our special hospitals have done this, but it is only just to the medical officers generally to say that a number of the most useful devices have been introduced quite independently of special conditions, and it is fair to assume that with young and energetic officers this is always likely to be the case.

WOUNDS OF THE JOINTS.

The experience gained in recent previous wars regarding the treatment of wounds of the joints has proved of small avail in the present campaign, because it was obtained almost entirely from observation of the lesions produced by rifle bullets, which had proved themselves of minor gravity and capable of healing spontaneously with good results when subjected to simple treatment founded on the sovereign principle of rest.

The problem of dealing with grossly infected joints, often enclosing a septic irregular fragment of shell and dirty clothing, perhaps further complicated by extensive fractures of the cancellous articular extremities of the bones, was therefore practically a new one to the surgeons engaged. Some definite facts have emerged from the first flood of difficulties encountered, and these may be shortly summarized as follows:

1. The wound of the soft parts clothing the joint is vastly more difficult to deal with than the articular cavity itself, and demands the most scrupulous care on the part of the surgeon.
2. The synovial capsule itself is capable of dealing unaided with an infection often of a really serious grade.
3. A strong tendency exists for an infection to localize itself, and the remaining portion of the capsule may remain free.
4. Drainage in the sense of the insertion of large tubes left in position for days or more is not only useless but also harmful.
5. That a gunshot wound of a joint cannot be dealt with too early, and with proper treatment forms one of the best subject wounds for primary suture.
6. That following the primary surgical intervention the main principle to be observed is that of complete rest gained by immobilization and extension.

General appreciation of these facts has resulted in the conclusion that a large majority of the joint injuries should be subjected to their chief active surgical procedure in the hospitals of the advanced lines, and hence the general hospitals at the present time receive only cases well upon the road to recovery, or such as present the more difficult problem of dealing with established infection and suppuration.

The line of treatment which has been adopted in the former class of case has been already laid down elsewhere (June 2nd, p. 718); it only remains to add that even cases which eventually do excellently often arrive on the lines of communication with synovial effusion and local redness over the joint and in the neighbourhood of the closed wound, signs due entirely to an exacerbation consequent on the disturbance inseparable from transport down the lines. Such cases usually settle down rapidly if only strict care be taken to maintain complete immobilization, while any premature intervention may be the direct cause of disaster.

The class of case may be first dealt with in which a patient arrives with a foreign body still occupying the joint cavity. This may be the result of the impracticability of early x-ray examination, the nature of or the small size of the foreign body, or of a large number of patients having to be rapidly dealt with.

If the foreign body be a rifle bullet, and the condition of the external wound satisfactory, no immediate action beyond fixation of the joint is advisable at this period. It is far safer to leave the bullet *in situ* until all chances of awakening or spreading an infection have passed by. The same attitude of masterly inactivity is to be recommended in instances in which the included foreign body consists of very small fragments of shells or bombs, especially if

the bodies lie without the actual confines of the articulating surfaces. Such foreign bodies may never need removal. Thirdly, when fragments of shell are of larger size and need removal they may be found to have rebounded from the surface of the bone and actually lie without the confines of the joint cavity, although the capsule has been wounded. Special care needs to be exercised in dealing with these cases, since portions of clothing carried before them by the shell fragments may still occupy the joint cavity. Lastly, the foreign body may be impacted more or less deeply in the articular end of the bone, and if a shell fragment it should be removed, although in a patient who has recently undergone transport undue haste in the procedure is not advisable.

Wounded joints which arrive with obvious local and general inflammatory signs need to be treated with great judgement. The condition may have been aggravated by transport and may rapidly improve when complete rest is assured. Again, the serious infection may be situated in the periarticular structures rather than in the joint itself. Precipitate action under these circumstances is to be deprecated. The safer plan is to place the limb at rest for twenty-four hours or longer, and observe the result, meanwhile making a puncture and withdrawing fluid, if present, for bacteriological examination. If want of improvement or the result of the bacteriological examination indicate the advisability of intervention, the type operation should be of the nature advocated by Colonel Gray—excision of the wound or wounds in the joint coverings, flushing of the synovial cavity after evacuation of its contents, and suture of the synovial membrane. The treatment of the external wound differs according to its size and condition. In some instances it may be closed completely, in others a drainage tube may be inserted down to the sutured capsule, or, where the wound is extensive or obviously not free from infection, it is better to leave it freely open and treat it by antiseptic measures until surgically sterile and suitable for secondary suture. Naturally some of the more extensive wounds must be left to heal by granulation.

The treatment of a freely suppurating joint requires to be of a different character; here the joint cavity must be maintained open and sterilization effected by an antiseptic method, of which Carrel's has undoubtedly given the best results. When, for instance, the cavity of the knee-joint in general needs to be drained, the method carried out by Captain Campbell and advocated by Captain Gill is worthy of special mention. It is generally agreed by all observers that when suppuration extends backwards from the knee the line of progress is not from the pouches lying on either side of the crucial ligaments but around the lateral aspects of the condyles—in point of fact, by the popliteus extension of the capsule on the outer side and the semi-membranosus extension on the inner. Hence posterior drainage from the centre of the joint is not only inconvenient to arrange but also inadequate to meet the requirements. Postero-lateral incisions have therefore been devised, but Campbell and Gill have regularized a method which simplifies greatly the accurate and adequate drainage of these regions. Lateral incisions having been made corresponding in position with the reflection of the synovial membrane from the femur, a pair of artery forceps is pushed down on the outer and inner aspects of the lower end of the femur respectively until the points of the forceps can be palpated in the popliteal space. An incision is then made down on to the guide thus furnished, and a direct route is established to the two bursal extensions from the posterior aspect of the joint, and by this Carrel's tubes are conducted for the requisite depth. Should still freer drainage be required, the incision is enlarged, the respective heads of the gastrocnemius exposed, and a portion of the origins of the muscle excised, so that a free opening is ensured. Further mention of the treatment of the extensions by the subcrural pouch, the internal intermuscular septum, beneath the popliteus or along the semimembranosus tendon is unnecessary. The upper pouch of the joint may need several instillation tubes, which are gradually decreased in number and totally removed at as early a date as possible.

For suppurating joints of some standing Rutherford Morison's method has been adopted with success.

The influence of a coexisting fracture on the prognosis in a joint injury is a matter of great moment in any class of case, but the frequency with which this condition is

met with in gunshot wounds invests it with a very special degree of importance.

There is little doubt that the actual risks to the safety of the limb attached to this complication were somewhat over-estimated at the commencement of the war, and that to-day, in the presence of a more satisfactory and rational treatment of the wound, and also the knowledge acquired as to the possibility of saving the joint entire, or submitting it to either primary, intermediate, or secondary excision, the prospects of avoiding amputation are much improved.

It may be laid down generally that tunne's, cavities containing missiles, fissures, and even T fractures, do not of necessity entail a very serious prognostic gravity provided the wound in the soft parts can be and is satisfactorily dealt with, and the fragment of shell removed.

In a large proportion of such injuries a more or less movable joint can be attained, and in many a perfect result. Still, in no form of injury does this more depend upon the continuous attention of the surgeon, care in the initial treatment of the joint, and subsequent daily precaution. Injuries affecting both bony elements are more serious, but may be treated by excision. Severely comminuted articular ends commonly need amputation, except where the single articular end can be removed, as in the case of the upper ends of the humerus and femur, or where bones, such as the carpal and tarsal, can be completely removed. The position to-day may be fairly summed up by the remark that, putting on one side articular injuries in which the bony destruction is irreparable, the fate of the case depends upon the success with which the wound of the soft parts surrounding the articulation is treated, the actual joint lesion taking a place of secondary importance.

EXCISION OF JOINTS FOR GUNSHOT INJURY.

The operation of excision is certainly struggling for a return to its former position as a procedure in military surgery. The operations were no doubt in older wars often performed for what would now be considered injuries not sufficiently extensive to demand so radical a procedure; further wound treatment was often defective. Yet excision occupied a prominent place until, with the introduction of the bullet of small calibre and ogival or dome-shaped tip, injuries of the joints began to be regarded as of minor importance. A revulsion in the latter opinion occurred early in this campaign, and some surgeons, notably Colonel H. M. W. Gray¹⁶ and Colonel A. Fullerton,¹⁷ have striven to enlarge the sphere of application of the operation. Growing experience has shown that it may be resorted to in well chosen cases in all three stages of the progress of a joint injury, with a distinct prospect of success under suitable conditions.

Early Excision.

By this is meant immediate operation at the casualty clearing station. It is obvious that a certain number of joints may be excised as an alternative to amputation. Thus a severe localized comminution of the lower end of the femur or the upper end of the tibia may render any chance of recovery with a useful limb improbable, while the uninjured shaft may still be of sufficient length to allow of ultimate union. The same remark may apply when both articular surfaces have been destroyed by a traversing missile. In the case of the upper end of the humerus, and also of the femur, comminuted fractures with destruction of the articular surface also form good subjects for the operation. In the case of the elbow a partial excision may often be done. The possibility of these procedures is limited, however, by the definite condition that circumstances will allow the patient to remain a sufficiently long time to be able to bear safely the risks of transport down the lines of communication to the general hospital.

Intermediate Excision.

This operation is that concerning which the gravest doubts were felt in the earlier stages of the war, and even now it can only be undertaken with the definite intention of following it at once by an amputation if the procedure is followed by local extension of infection and signs of systemic absorption. It has, however, proved that excision may be a successful alternative when the severity of the general and local signs seems to indicate amputation as the only resource. The explanation of this experience can

be found solely in the facts that better drainage can be ensured when the articular ends of the bones have been removed, and the wound can be treated more effectively. It is a striking fact that progressive osteomyelitis from the sawn ends of the bone has not developed, especially when the frequency of this complication in ill-drained comminuted fractures is remembered. Two special details need mention: (1) Should the synovial membrane be removed? As a general rule this question is to be answered in the negative. The synovial surface in itself is better capable of dealing with an infection than a freshly cut layer of subsynovial areolar tissue; further, when no extensions of suppuration have taken place it forms an effective barrier against such extensions when proper drainage is provided. (2) Should the refreshed ends of the bones be placed in apposition, or be temporarily kept widely separated by extension? The latter plan has been most generally adopted. The excision of bone should be of the most limited extent in the case of the knee. Lastly, in this joint as in all others, excision is not to be regarded as a proper alternative where efficient drainage can be expected to ensure the end desired.

Late Excision.

The principles guiding the performance of excision at a later date do not materially differ from those laid down above; moreover, as far as the hospitals on the lines of communication are concerned, the distinction is rather one of date than of the actual pathological conditions to be dealt with.

THE RESULTS OBTAINED IN WOUNDS OF THE KNEE-JOINT.

Any writer concerned with wounds of the articulations instinctively thinks of the knee-joint, the most troublesome to treat, and that in which a good result is most gratifying. Two small series of cases treated by Captain Campbell and Captain Gill respectively may give some indication of the results being attained.

In 60 consecutive cases (Campbell) coming from the fighting on the Somme, 14 were classified as very severe, 17 as severe, 13 as slight, and 16 as having retained foreign bodies. Three died and one required amputation. The three deaths were due in two cases to secondary haemorrhage and in one to septicaemia. The other 56 cases were transferred to England in good condition, the great majority with every prospect of good movable joints.

In a second series of 69 cases (Gill), in 31 the injury was inflicted by a bullet, and in all an uninterrupted recovery was obtained by rest alone.

Amongst the remaining 38 cases one died as a result of meningitis following a fracture of the skull, and in four cases, one of which developed delayed tetanus and recovered, amputation was required.

Thus in 129 cases amputation was required in 3.87 per cent., and death occurred in 3.1 per cent.

A much larger series of cases, treated by different surgeons at Rouen, has been analysed by Colonel Gilbert Barling, and the results are shown in the appended table:

Cases of Wound of Knee-joint operated on at Rouen Hospitals in the second half of 1916, excluding all those which were so quiet that nothing was done, and all those submitted to early amputation as conservative measures were inapplicable.

1. Total cases of injury to knee operated on	845
2. With bone injury	438
3. Without bone injury	407
4. Wound excised and closed	322
5. Cases with wounds excised and closed requiring further operation	82=25.5%
6. Wound excised and packed	336
7. Cases with wounds excised and packed requiring further operation	128=38.4%
8. Excision of knee	42
9. Arthrectomy, partial or complete	15
10. Excisions or arthrectomies amputated	13=22.8%
11. Deaths after excision or arthrectomy	13=22.8%
12. Amputation without excision	151
13. Deaths after amputation without excision	49=32.4%
14. Total amputations	164=19.4%
15. Total mortality	72= 8.5%

Note.—One hospital with a large number of cases was unable to separate the cases under headings 4 and 6.

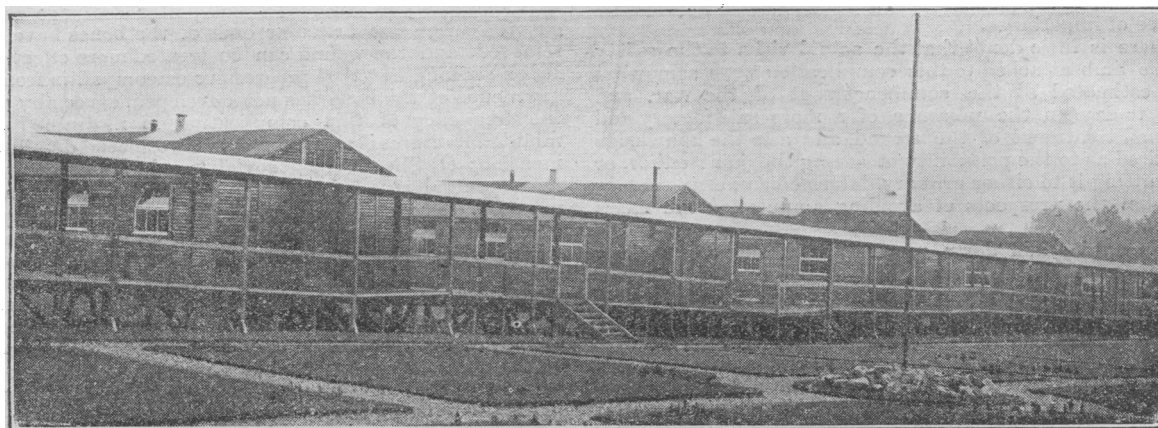


FIG. 6.—View of St. John Ambulance Brigade Hospital, showing connexion of the huts by an open corridor.

INJURIES TO THE HEAD.

A great change has taken place since the commencement of the war both in the nature of the cases and in their actual number. This change depends on the one hand on the fact that a larger number of these injuries are retained and operated upon at the front lines, and on the other on the protection afforded to the head by the helmet. The early treatment of these injuries has already been dealt with; it suffices here to say that the patients which now arrive have either already been operated upon and are in good condition, or they come down already suffering from septic complications. The general lines governing the treatment of the latter class of case have been admirably laid down in a paper in the *British Journal of Surgery* by Sargent and Holmes,¹⁸ and certain points in the technique of the operative procedure elaborated. These authors have also dealt with the anatomical and histological changes associated with traumatic injuries and infected wounds of the brain and their bearing on the surgical treatment of these conditions. Further, examination of a considerable number of patients some months after their return to England proved much more satisfactory than had been generally expected. It was found that the proportion of patients who die after transference to England is small; later complications, such as cerebral abscess, are comparatively rare, and serious sequelae, such as insanity and epilepsy, are much less common than had been foretold. In only 15 per cent. of the patients examined, however, had more than one year elapsed from the date of the injury. It also appeared that many patients with foreign bodies deeply lodged in the brain recover, and are scarcely more liable to serious complications than men in whom the brain has been merely exposed and lacerated. These conclusions are obviously only tentative, but as far as they go appear hopeful.

Holmes and Sargent¹⁹ have also described a condition hitherto rarely seen, and established a definite symptom-syndrome for its recognition. It is characterized by an immediate spastic paralysis of the legs, and frequently associated with spastic paresis of the proximal segments of the upper limbs; they have shown it to be due to occlusion of the superior longitudinal sinus or of the veins that enter it, by a depressed fracture of the vertex of the skull. Experience showed the results of surgical interference with cases of this class to have been extremely unsatisfactory. Thus, among 39 cases observed which were operated upon either by the authors or others, 15 deaths occurred, while among 37 cases in which no operation was undertaken only one died before transference to England. While it is allowed that these figures have no absolute value, as naturally only the most serious cases were selected for operation, and in seven of the fatal cases direct injury to the brain was present in addition, yet the results emphasized the danger of operation. Moreover, the uncomplicated cases showed a remarkable tendency to improve, probably owing to the free venous anastomosis permitting a re-establishment of the circulation.

An important contribution to the localization of function in the brain has been published by Lister and Holmes,²⁰ who from a study of a large number of cases with injury in the occipital region were able to determine the relative

positions in the cortical visual areas of the foci that subserve vision of separate portions of the visual fields. They bring forward strong evidence with regard to the site for the centre for macular or direct central vision, of which very little had been previously known.

The following conclusions are come to:

1. The upper half of each retina is represented in the dorsal, and the lower in the ventral, part of each visual area.
2. The centre for macular or central vision lies in the posterior extremities of the visual areas, probably on the margins and the lateral surfaces of the occipital poles.
3. That portion of each upper quadrant of the retina in the immediate neighbourhood of, and including the adjacent part of, the fovea centralis is represented in the upper and posterior part of the visual area in the hemisphere of the same side, and vice versa.
4. The centre for vision subserved by the periphery of the retinae is probably situated in the anterior end of the visual area, and the serial concentric zones of the retina from the macula to the periphery are probably represented in this order from behind forwards in the visual area.

Holmes and Smith have recorded observations on the nature and localization of motor apraxia, or the inability to perform purposeful actions despite the preservation of movement and power, and in disturbance of the faculty of localizing objects in the external world by vision.

Probably in no other branch of medicine have so many and such difficult problems arisen as in the treatment of wounds and diseases of the nervous system. Further, in this field an extraordinary opportunity has occurred to observe, analyse, and record the effects of local lesions, many of which are rarely, if ever, seen in civil life. When the results of this work are eventually correlated, they must throw much light on the physiology and the symptoms of disturbance of different parts of the brain, spinal cord, and peripheral nerves, and thus increase our knowledge of the diagnosis and treatment of nervous diseases. Special arrangements have been made in order that cases under early observation in France should be sent to special hospitals in England, so that continuous records will be maintained of a very large number of patients.

NOTE BY COLONEL PERCY SARGENT.

I am indebted to Colonel Sargent for the following summary of his opinions:

The very large experience gained of gunshot wounds of the head has led to a considerable degree of modification in their treatment. Immediate routine operation, often incomplete and, in the absence of full neurological information and x-ray examination, sometimes unnecessary and even misdirected, is no longer widely practised. It has long since been made abundantly clear that early evacuation of operated cases is often followed by disaster. As it is impossible to operate upon these cases and to retain them at the clearing stations for a period which renders transportation safe, more especially during times of great military activity, the practice now generally adopted is to transfer them without operation as soon as possible to hospitals further down the line. It has been made quite

clear that surgical intervention is rarely required for the relief of cerebral symptoms, whether general or focal. Its chief aim is the prevention of intradural infection. On this conception all cases of gunshot wounds of the head fall into one of two categories, according to whether the dura mater has or has not been penetrated. Non-penetrating wounds have a low rate of mortality, whether operated upon or not, provided that the surgeon respects the integrity of the dura mater.

It is customary, therefore, to do in these cases only as much as may seem advisable to ensure speedy healing, such as excision of the edges of the wound, removal where necessary of bony fragments, and partial or complete closure of the gap in the scalp either by suture or by some form of plastic operation.

Penetrating wounds, on the other hand, afford more room for difference of opinion regarding their treatment. Individual cases continue to present difficulties even to those who have seen large numbers, but, broadly speaking, there is a consensus of opinion in favour of the following line of treatment: The wounds having been cleansed and dressed, the patient is transferred as soon as possible to a hospital where he can be retained for at least a fortnight after the operation. A complete neurological and radiographic examination is made and the operative treatment then directed according to the diagnosis thus arrived at. In some cases of penetrating wounds no operation is indicated, such as those in which a bullet has passed completely through the head; or those in which a bullet or a metallic fragment is embedded in the brain at a distance from a small clean entrance wound, and is giving rise to no symptoms. Another class of case for which operative interference is usually contra-indicated is that in which the longitudinal sinus has been injured. Cases where a track from the scalp wound leads down to indriven bony fragments, or to an easily accessible missile are operated upon, briefly, as follows: A moderately large flap is turned down after resection of all damaged tissue round the scalp wound; the bony opening is enlarged sufficiently to expose thoroughly the opening in the dura mater; the indriven fragments of bone and metal are removed under a constant stream of hot physiological saline solution; and the track is drained by a celluloid, metal, or rubber tube brought out through the original wound. In cases of more superficial cerebral laceration, where track drainage is unnecessary, the principle is employed of covering the denuded brain by some plastic operation on the scalp; in these circumstances drainage tubes emerging from the angles of the scalp flap are usually employed for a few days.

Retained Missiles.

Opinions still vary regarding the advisability of operating for the removal of bullets or shell fragments. There is

much evidence to show that these foreign bodies are well retained, and, apart from the uncommon accident of late suppuration, cause no symptoms. It has been stated by more than one writer that bullets embedded in the brain move about under the influence of gravity. The evidence for this view is wholly unconvincing. Removal of bullets, even when the wounds have healed and the risk of septic infection thereby is largely minimized, must be, even in

skilled hands, attended by an amount of damage which in most cases would have more serious neurological consequences than could the presence of an aseptic bullet.

Primary removal of a deeply-seated missile carries with it the additional risk of septic infection. For these reasons the usual practice is to leave alone such missiles.

The treatment of indriven fragments of bone is more debatable. When

driven into the brain by a missile which is itself retained, the bony fragments are rarely, if ever, more deeply placed than the projectile. When driven in by the impact of a missile which does not itself enter the cranial cavity, the bony fragments are rarely found so deeply situated but that they can be removed along the track with little, if any, additional damage being done.

With regard to the septicity of these indriven metallic and bony fragments, it has been found that a large proportion, when dropped into culture media immediately upon removal, fail to provoke any bacterial growth, either aerobically or anaerobically.

The question of the intracranial pressure has been the subject of repeated observation. Among the conclusions of practical importance which have been arrived at are the following:

1. Apart from the rare instances of extensive intracranial haemorrhage, traumatic oedema, whilst playing an important part in symptomatology, does not reach a sufficient degree of intensity to endanger life.

2. The instances of severe intracranial haemorrhage not rapidly fatal are very few; and even amongst these there is a certain number which surgical intervention is not likely to save. Experience has shown that an intracranial haemorrhage which is sufficiently severe to demand operative relief, and which can be recovered from, gives unmistakable signs of its progress. The operation can be deliberately planned and carried out with the definite object in view. Exploratory operations on the

chance of discovering a haemorrhage are rarely if ever called for.

3. In case of intracranial pressure from secondary oedema which is causing severe headache and herniation of brain, this can almost always be controlled by lumbar puncture. Occasionally contralateral decompression has been done for these cases and has afforded good results.

Such evidence as is at present available from the later results (six months to two years) is all in support of the general policy of treatment outlined above.

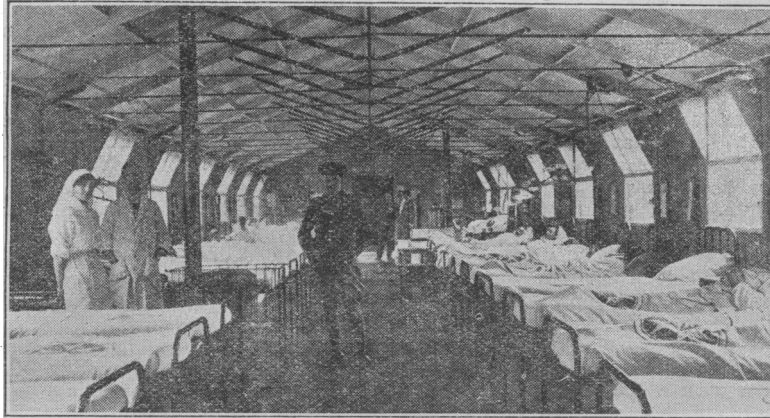


FIG. 7.—Interior of a ward of the St. John Ambulance Brigade Hospital.

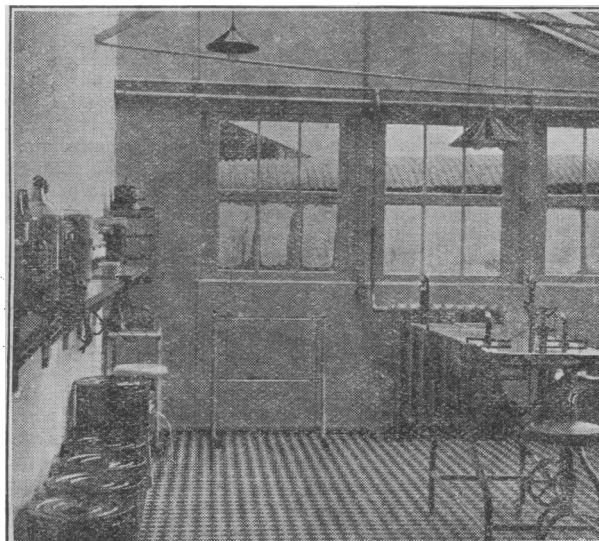


FIG. 8.—Interior of the operating theatre of the St. John Ambulance Brigade Hospital.

The steel helmets have played an important part. The study of cranial wounds before and after their general adoption brings to light many interesting points. The outstanding feature, however, is that which concerns the penetration of the dura mater. The proportion of penetrating wounds has very largely diminished, as also has the mortality, another amongst many indications that the surgeon cannot attach too much importance to the integrity of this membrane, or treat it with too much respect.

INJURIES TO THE SPINAL CORD.

Wounds and injuries of the spinal cord, when amenable to treatment, demand early surgical intervention. At the commencement of this war but little was known regarding the actual structural changes attendant on gunshot injuries, and what was known was concerned mainly with the changes which were found in spinal cords examined at a comparatively late date. The position of the surgeon was rendered yet the more difficult, in that past clinical experience had shown the extreme difficulty which exists in forming a correct prognosis, particularly in view of the remarkable ultimate recoveries observed in patients whose primary symptoms had not been able to be distinguished from those observed as attending total destructive lesions.

In order, therefore, to recognize when surgical intervention can be undertaken with a reasonable prospect of success, it was necessary to obtain an accurate idea of the nature of the pathological changes produced in the cord by modern projectiles. An investigation on this subject was undertaken by Gordon Holmes.²¹ He found that even slight local injuries are very frequently associated with extensive oedema, haemorrhages, softenings, and often with ascending cavity formation, which may extend a considerable distance both above and below the level of the original injury or wound. These changes he refers to the concussion effect produced by the missile through the walls of the spinal canal; they may exist even without the presence of a fracture of the vertebrae. Such changes can obviously not be relieved by any reasonable operation, and the fact that, apart from the secondary cavities that develop later, they occur immediately or within a very short time of the infliction of the injury, diminishes the favourable prospect of any surgical intervention. In some cases undoubtedly the symptoms are largely or in part due to compression of the spinal cord by either the missile or a fragment of depressed bone, but numerous examinations have proved that even in these the same intraspinal lesions exist.

Even relatively slight injuries often produce for the first few days, the period when operation offers the best chance of success, symptoms that may be confused with those of total and irreparable damage to the cord, and some clinical indication of the severity of the spinal injury is consequently necessary before an operation can be reasonably undertaken. This question was investigated in a large number of cases and the conclusions were published in the same lectures. These are to the effect that the safest guide to the severity of the injury is afforded by the form and character of the sensory disturbances, and especially by the changes and modifications in the reflexes of the affected limbs.

In most cases the site of the wound or a radiographic examination permits an accurate diagnosis of the medullary lesion, but not infrequently this can be determined only by a study of the symptoms produced by it. The method by which an accurate local diagnosis can be made is also dealt with in these lectures. Here, too, many important and interesting symptoms which result from injuries to different portions of the spinal cord are described. It was found, for example, that when its lower cervical and the upper thoracic segments were severely affected, the patients often presented a serious symptom-syndrome characterized by hypothermia, bradycardia, low blood pressure, reduced secretion of urine, and mental hebetude. The body temperature may fall as low as 80° F. (27° C.), the pulse-rate to 35 or 40 per minute, the blood pressure to 60 mm. of mercury, and only 4 to 8 oz. of urine may be secreted in the twenty-four hours.

Injuries to the region from which the vasomotor fibres to the kidneys pass off may, on the other hand, produce an extraordinary polyuria, and lesions in the higher cervical segments were shown to be often associated with hypernrexia.

Attention has been drawn by T. R. Elliott²² to the occurrence of spinal lesions in men who have been exposed to shell explosions in their immediate vicinity, but who escaped direct injuries.

The acquisition of wider knowledge has not, however, greatly widened the scope of operative intervention. Operations are still for the most part confined (1) to cases in which a radiographic or direct examination reveals the presence of displaced and depressed fragments of bone or the lodgement of foreign bodies either within the canal or buried in the cord (it may be mentioned that several cases have been observed where retained bullets have travelled long distances within the spinal canal, particularly in its lower part); (2) to cases in which the patients suffer severe and unbearable pain; (3) to cases in which pressure from haemorrhage around the cord is suspected, such cases being very rare. An additional class may be added in which a late operation is performed on the chance of some improvement being gained, mainly as a question of expediency. Patients with injuries to the nerves of the cauda equina have as a rule been evacuated to England.

No striking change in operative technique has been developed, beyond the general tendency to partial rather than classical laminectomies, and perhaps the development of an increased confidence in the utility of placing a muscle graft over the opening in the spinal membranes when leakage of cerebro-spinal fluid has been associated with the performance of the operation. An intact dura has throughout been an important immediate prognostic element, as in the case of injuries to the head.

Early drainage of the bladder by a suprapubic tube has been advocated by Percy Sargent since the commencement of the campaign, but the difficulties in the transport of patients thus operated upon, and the increased responsibility devolving on the nurse in keeping the back in good condition, have militated against an extensive adoption of this measure.

Injuries to the peripheral nerves have been extremely common; it has indeed been estimated that in 18 to 20 per cent. of all limb wounds slight or more serious lesions of the large nerve trunks coexist. But owing to the facts that when, as is usually the case, extensive septic wounds are present, the early surgical treatment of nerve injuries is impracticable, and that the patients with small and clean wounds can be safely transferred to England, neither the treatment nor the study of these injuries has been an urgent question in the general hospitals on the lines of communication in France.

ABDOMINAL INJURIES.

The chief interest in injuries to the abdomen has rightly been transferred from the general hospitals to special hospitals at an advanced line or to the highly developed casualty clearing stations. Prior to the summer of 1915, however, the great majority of injuries to the abdominal viscera were dealt with on the expectant system, and such of the patients as survived arrived in the general hospitals. The experience gained from the observation of these afforded some information regarding the prognosis of wounds of both hollow and solid viscera, which may in the future not be so readily obtained.

The enormous mortality attending injuries to the small intestine was clearly demonstrated, both by the comparatively small number of patients arriving, and by the simple nature of the injuries found at *post-mortem* examination compared with the extensive and multiple character of the lesions which have been almost uniformly discovered by early operations. This experience exerted a healthy influence in supporting the advisability of early operation. The lesser fatality attending wounds of the colon, excluding the transverse colon and the sigmoid flexure, was also clearly brought out, since a larger proportion of wounds of the large gut arrived at the general hospitals, and of these more than 50 per cent. recovered sufficiently to be transferred to England in good condition. This number obviously has no bearing on the actual mortality of wounds of the colon, but compared with a percentage recovery of less than 16 per cent. in a small series of minor injuries to the small intestine, it is sufficiently striking.

A few points of some interest also emerged from the series of *post-mortem* examinations made on patients who had survived several days; thus the general character of the peritonitis in cases of wounds of the small intestine,

and the localized nature of that developing in consequence of wounds of the large intestine; the observation that when the wound track traversed the psoas muscle and its sheath, extravasation of faecal contents extended to the thigh, and, indeed, might travel the whole length of the lower limb; that, while patients dying from the effects of wounds of the small intestine uniformly succumbed to peritoneal infection, deaths following wounds of the colon were, in 40 per cent. of all the cases, the result of a general infection from the septic wound of the soft parts of the trunk, and not from the peritoneum itself, the main feature of the general infection being a purulent bronchitis; lastly, in a series of *post-mortem* examinations made by Captain Henry, in every case a general *post-mortem* invasion of the blood stream by anaërobic organisms was discovered.

Experience again proved the practical futility of performing operations for the closure of intestinal wounds after thirty-six hours has elapsed from the time of injury, and it is probable that any successes obtained in this field can be counted upon the fingers. On the other hand, the good results often obtained by performing a proximal colostomy in large wounds involving the colon, and thus preventing the occurrence of the late systemic infection referred to above, have been amply proved. The few cases in which an attempt has been made to obtain the same result by making an intestinal short circuit by anastomosis have not been encouraging, and it is obvious that this class of case is not a favourable one for such procedure, both by reason of the general condition of the patient and the difficulty in performing a clean operation.

No novel features have been disclosed by observation of the numerous instances of wounds to the solid abdominal viscera, except that perhaps more attention has been given to interference with their secretory activity, and that the favourable course commonly following these injuries in the absence of serious septic complications has tended to confirm the propriety of maintaining an expectant attitude in the question of surgical intervention. Speaking generally, it may be said that the formation of an abscess or the occurrence of secondary haemorrhage are the only indications for interference at the period at which the patients reach the general hospitals. Septic infection has been the common cause of death in all cases of fatal injury to the solid viscera, and in 40 per cent. of deaths from wounds of the liver secondary haemorrhage has accounted for the fatal issue.

Intraperitoneal injuries to the urinary bladder, even discovered during operation, have been rare throughout the campaign, and for some reason probably connected with the conditions of trench warfare extraperitoneal wounds have become far less often seen than in the earlier stages of the war. These latter cases were the source of much interest because they were sometimes difficult to diagnose from injury to the pelvic small intestine in the early stage, and also because treatment by simple suprapubic cystostomy was found so successful. Of thirty such consecutive operations only two proved unsuccessful, and in each of these comminuted fractures of the pelvis were coexistent. If treated expectantly, in many instances the urine escaped freely from apertures in the abdominal wall, the buttock, or the thigh for a week or ten days, and the patients appeared to be doing well, when infection of the urine took place, extended to the bladder, and toxæmia followed. Even in the latter class of case, however, a late operation may save the patient.

The condition of cases arriving at the general hospitals subsequently to the primary operations at the advanced lines deserves a word of mention, although the patients are for the most part birds of passage.

The general results have been remarkably good, the most common defect, now not so common as in the earlier stages of the adoption of early operation, has been incomplete union of the wound in the abdominal wall. In some cases this has been accounted for by a primary use of the initial entry or exit aperture for the site of the exploratory incision, in others from the persistency of a gap left for a drainage tube; but beyond these complicating factors an obvious difficulty has been experienced in obtaining firm primary union. In some cases this may have depended on an actual deficiency in vitality of the patient, but in the majority it has undoubtedly been due to infection, and when it is borne in mind that these operations are performed on the subjects of intestinal perforations in whom infected blood is present and has to be evacuated from the

abdominal cavity, it is not to be surprised at. Such wounds have usually healed readily by granulation. The next occasional trouble has been the secondary formation of abscesses or fistulae. These have not been common, the abscesses usually following colic wounds and the fistulae wounds of the small intestine. It is noteworthy that fistulae have formed secondarily in several cases in which the primary exploration has been negative—a fact bearing on the common occurrence of severe contusion of the wall of the intestine unaccompanied by perforation. As a rule, the bowels have acted regularly and well; in some instances diarrhoea has been troublesome, and the writer has only seen one patient in whom secondary obstruction was caused by adhesions. On the whole, the evidence seems against troublesome peritoneal adhesions developing with any degree of frequency. In one *post-mortem* examination made upon a patient who died from pneumonia the abdominal cavity was absolutely free from adhesions, and an end-to-end anastomosis was so perfect as to be with difficulty discovered. As is usually the case, however, the bowel on the proximal side of the line of union was already somewhat dilated.

RADIOGRAPHY.*

Considerable advance in the localization of foreign bodies has been made in the general hospitals on the lines of communication during the progress of the campaign.

While the majority of surgeons are agreed that the greatest radiographic assistance which they receive in the removal of foreign bodies is afforded either by stereoscopic

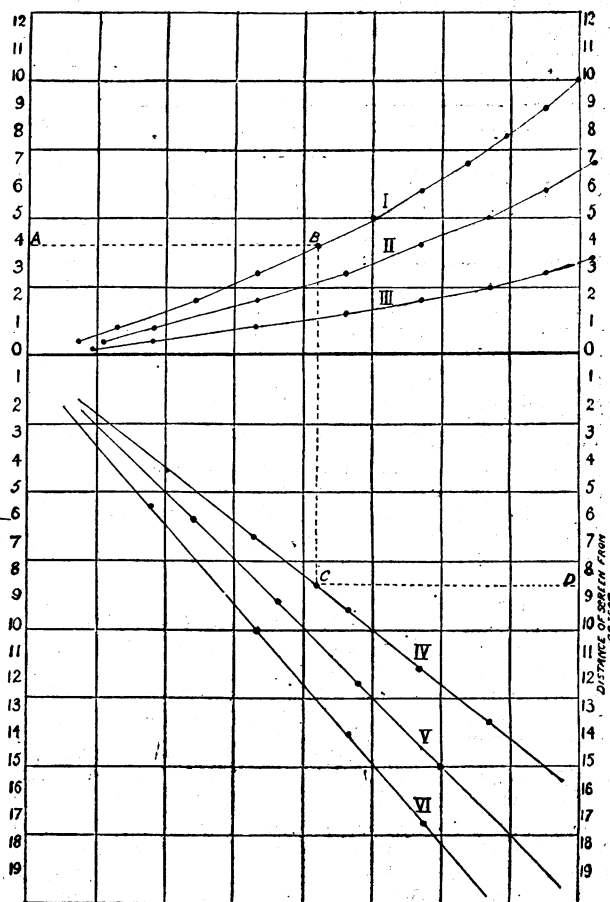


FIG. 9.—I, Curve for a displacement of the focus of 150 mm. II, Curve for a displacement of the focus of 100 mm. III, Curve for a displacement of the focus of 50 mm. IV, Correction for a distance from the screen to the focus of 400 mm. V, Correction for a distance from the screen to the focus of 500 mm. VI, Correction for a distance from the screen to the focus of 600 mm.

skiagrams, or else by two plates taken at planes at right angles to one another—usually antero-posterior and lateral—there are situations in the body, such as the thorax, abdomen, and hip region, where it is more convenient to be provided with the depth of the foreign body in centimetres under a certain spot.

* The writer is indebted to Major Curtis Webb for the technical details contained in this section.

The prime credit of evolving a method for estimating the position of a foreign body must be accorded to Mackenzie Davidson, but in the early days of the war Dr. Hampson worked out a modification of Davidson's principle whereby the depth of the foreign body from the screen or plate could be easily and quickly determined, and several ingenious modifications of a mechanical device attached to a fluorescent screen have been put upon the market based in principle on Hampson's work.

In October, 1914, M. Paul Wigny, director of the Rouen Electric Light Company, worked out a formula and chart (Fig. 9) for Major Curtis Webb; subsequently the formula was independently evolved, and published in England in 1915. This formula is based on Hampson's principle, and has been extensively utilized by Major Curtis Webb, who has supplied the following details as to its application:

In Figure 10 τ is the table, and r the part of the patient in which lies the foreign body at an unknown depth (x); L = the distance between the anticathode and plate;

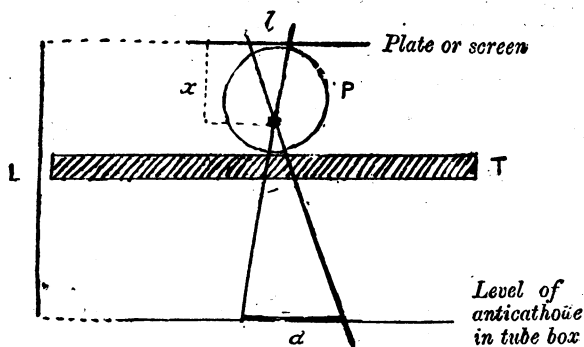


FIG. 10.

d = the horizontal movement of the tube between the two exposures; l = the distance between the two shadows on the plate or screen. With these indications it is easy to work out the formula:

$$x = \frac{l \times L}{d + l}$$

The procedure is as follows: First centre the tube under the part where the foreign body is seen, and close the diaphragm down until the foreign body is just enclosed by the aperture. Mark the skin over the point, and the foreign body will lie vertically under it. Place a plate in position with its centre about over the foreign body, move the tube a few centimetres (4 or 5) one way, expose and then move the tube back 10 centimetres, and expose again on the same plate. On developing, there will be two shadows: the distance in centimetres between two corresponding points of the shadows will be the distance l ; d should be 10 cm., and L should be 50 cm. On many x-ray couches there are arrangements for securing this last factor, and where this is the case the chart (Fig. 9) will enable the exact depth of the foreign body to be ascertained without calculation in the following way:

In the upper left side of the chart are a series of numbers corresponding to the distance between the shadows. Take this figure, follow the horizontal line until it touches the curve corresponding to the amount of lateral movement of the plate—usually 10 cm. Then follow the perpendicular from there until it impinges on the line corresponding to the distance between the plate and the anticathode (L), and then trace the horizontal from this point towards the right of the chart. The example in the chart is indicated by the line $A B C D$, where a distance between shadows of 4 cm., a movement of the tube of 15 cm., and 40 cm. between plate and anticathode corresponds to a depth of the foreign body of 8.5 cm.

If a couch has been extemporized the distance of the anticathode from the top of the couch can be measured once and for all and noted, and the distance of the plate, where lying on the part under examination, from the top of the table can be added to the above known distance and the depth of the foreign body finally worked out from the formula; or the part can be raised on pillows until L is approximately 50 cm. From a surgical point of view approximation is all that is necessary, for note that, if it be endeavoured to arrange that L be 50 cm., but for some

reason it be either 48 or 52 cm., then x will be either 8 or 8½. Should, for example, l be taken as 2 cm., then a difference of ½ cm. is negligible in an ordinary removal of a foreign body. However, very little ingenuity is required to ensure L being fairly accurately 50 cm.

For localization of foreign bodies in the eye, an excellent head rest has been devised by Major Higham Cooper, which is both simple, rapid, accurate, and convenient.

In civil practice it has been customary to radiograph the eye with the patient in the sitting position. This is impracticable in the majority of wounded soldiers,

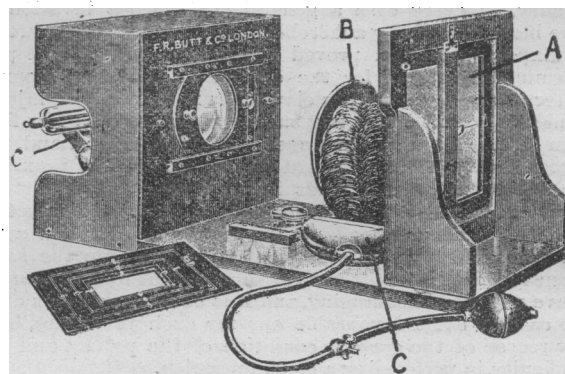


FIG. 11.

hence the head rest, illustrated in Fig. 11, was designed to enable men to be x-rayed while in bed in the wards.

The apparatus is either arranged across the bed, or made to replace the pillow, the patient's head being placed in the position shown in Fig. 11, pressed against a plate-holder A , provided with cross wires. The patient's head rests upon an air pillow, which can be inflated to raise it to the height desired. An upright of thin wood, B , is then pushed up to the other side of the head, and clamped to immobilize the head. The x-ray tube (previously centred on the intersection of the cross wires on the plate-holder) is held in a clamp, C , capable of a 3 cm. shift to either side of the central position against stops. Hence no measurements require to be made, as both the distance of the tube and the displacements are fixed.

In localizing foreign bodies in the eye a metal marker must be placed in some known relation to the centre of the cornea. In head injuries the markers may be placed as desired. Localization is done by the graphic method for vertical and horizontal position, and the usual formula is employed to calculate depth. The negatives possess also the advantage of being stereoscopic.

For working out the exact position from a pair of stereoscopic plates a most excellent and accurate method has

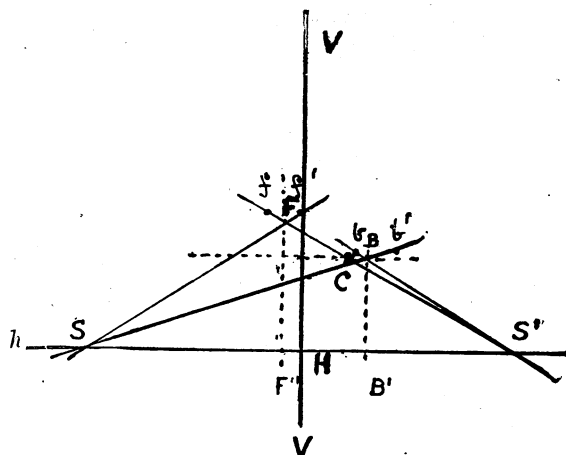


FIG. 12.

recently been published which dispenses with the Mackenzie Davidson localizer.

A typical case will make this clear (Fig. 12). In this case the tip of the fuse wire was exactly 9 mm. under and on the same plane as the centre of the pupil when the

Name.....

Date.....

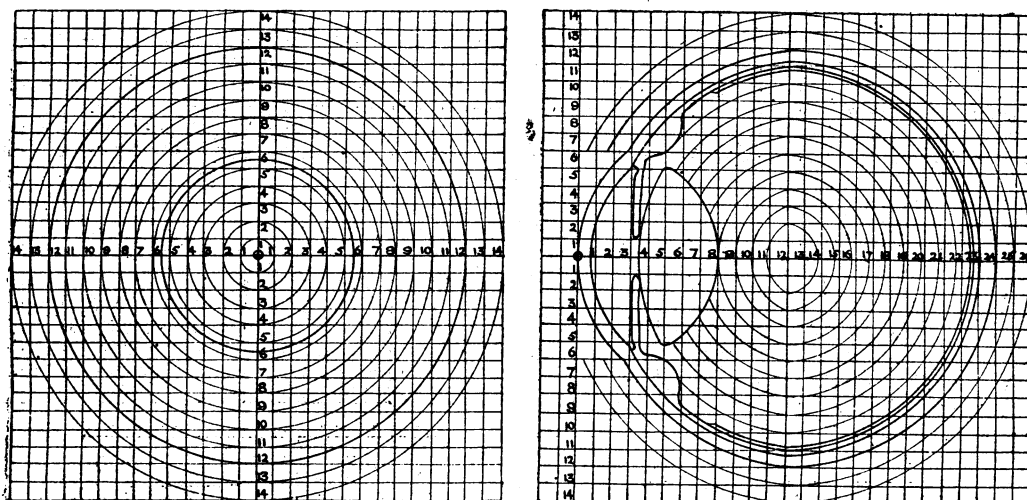


FIG. 13.—Plot out the foreign body on the left diagram, and read off its distance in mm. from the Central Corneal Axis (C.C.A.). Imagine the right diagram rotated round the line of the C.C.A. to the plane passing through the foreign body. The number of mm. the foreign body is from the C.C.A. is counted in the plane tangential to the centre of the anterior surface of the cornea, and the foreign body is plotted out at the appropriate depth. It will be seen whether the foreign body is inside or outside the globe, and how many mm. it is internal or external to the outer surface of the sclerotic.

The foreign body ismm. { above the central corneal axis.
below

.....mm. to the { nasal side of the central corneal axis.
temporal

.....mm. deep to the plane tangential to the centre of the anterior surface of the cornea.

The charts show the foreign body to be { inside the globe.....mm. { internal to the outer surface of the sclerotic.
outside external

patient looked at some distant object with the sound eye, the patient lying on his back so that the horizontal line *h h* may be considered as passing from the vertex towards the chin. Obviously, then, the vertical line, *v v*, will be parallel to the central corneal axis (C.C.A.).

Now, on either side of the point of intersection *H* measure two distances, *H s*, *H s'*, each of 3 cm., then the points *s* and *s'* will correspond to the respective positions of the anticathode of the tubes at the two exposures, and *f* and *f'* the shadows of the tip of the fuse wire, and *b* and *b'* the shadows of the foreign body, and *r* and *r'* will be the respective true positions of the tip of the fuse wire and of the foreign body. From *r* and *r'* drop two verticals *r r'* and *b b'*; measure *r r'* and *b b'*, then *r r'* minus *b b'* will be the depth of the foreign body. Again, draw a horizontal line through *b* parallel to *h h*, and as it is known that *r* was 9 mm. below the central corneal axis, then the centre of the pupil is indicated by the point *c*; then the distance *c b* will be the distance of the foreign body above or below (in this case above) C.C.A. Finally, knowing the distance of the anticathode from the plate, we can determine the distance of the tip of the fuse wire *r* from the plate—using the formula

$$x = \frac{b \times L}{d + l}$$

—by the distance between the shadows *f* and *f'*, and in the same way the distance of *b* from the plate can be estimated. If the distance of *r* be greater than the distance of *b* from the plate, *b* is that much on the temporal side of the C.C.A., as is indicated by the difference between the two distances. On the other hand, if *b* is further from the plate than *r*, then the foreign body will be that much to the nasal side. In the case typified the exact position of the foreign body was

4 mm. deep to
3 mm. above
exactly on vertical
∴ in globe. } C.C.A.

The accompanying charts (Fig. 13) have been suggested by Colonel Lister for demonstrating the position of foreign bodies in the eye, on the lines laid down by Captain J. Herbert Fisher, F.R.C.S., R.A.M.C., in his article in the *Ophthalmic Review*.

EMPLOYMENT OF RADIOSCOPY.

It would appear expedient specially to emphasize the danger of substituting radiology for radiography in the localization of foreign bodies except in occasional cases. When a number of cases require attention, radiology is undoubtedly the more expeditious, but more than one operator in France has had his face and hands severely burnt by excessive use of the screen. Further, the radiographic plate, even though the structures have a double contour, can afford very definite assistance to the surgeon at the time of operation.

The removal of foreign bodies under the fluorescent screen has been employed to a considerable extent in some hospitals, the following method and precautions being adopted:

The patient is laid on the x-ray couch and anaesthetized. The part to be examined is cleansed and covered with a sterile towel, upon which the fluorescent screen is placed. The current being turned on, the diaphragm on the tube box beneath the table is reduced in diameter enough to define the foreign body clearly, which procedure also cuts off all unnecessary rays, and so saves the operator's hands. By pressing on the skin in the neighbourhood of the foreign body and noting its maximum movement it is easy to ascertain at what point the foreign body is nearest to the surface, and it can then be determined whether it should be removed through the original track or whether a fresh incision should be made directly over it. Which-ever proceeding be decided upon, the point of a forceps is now introduced and pushed on until it reaches the foreign body. By moving the points up and down alternately it can be noted which movement causes the greatest displacement of the foreign body, and thus it is known whether the forceps occupy a plane above or below it. A little practice enables the forceps to be brought quickly into contact with the foreign body, when they are opened just sufficiently widely to allow it to be grasped without the inclusion of muscle or other structures surrounding it.

As an extra precaution it is well to place a sheet of aluminium 1 mm. in thickness over the diaphragm in order to cut off the soft rays.

RAPID LOCALIZATION OF BULLETS OR SHRAPNEL BALLS FROM A SINGLE RADIOGRAPH ON A SINGLE PLATE.

This method, devised by Captain Pirie, C.A.M.S.,²³ is obviously limited in application, since it assumes that only

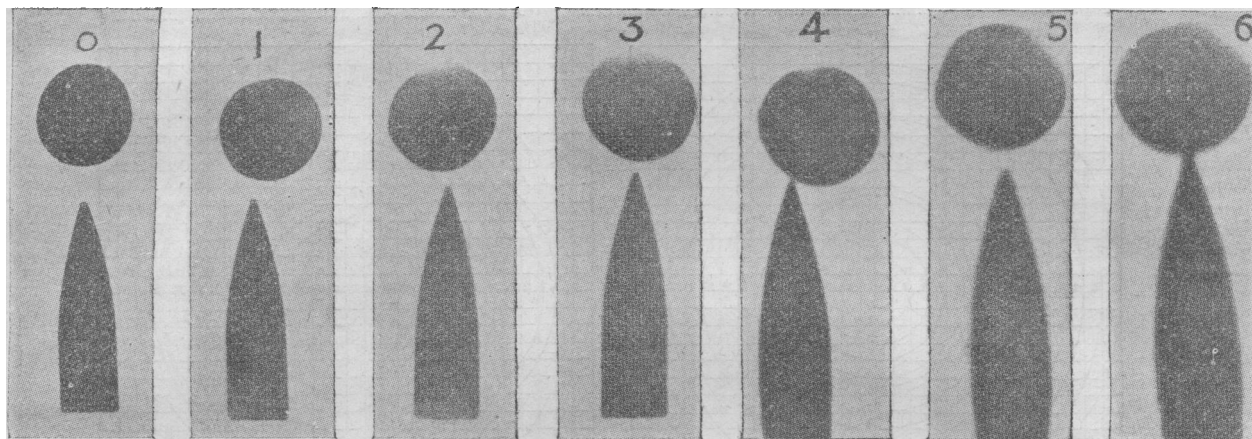


FIG. 14.—Showing bullets and shrapnel balls radiographed at the distances mentioned in inches.

bullets and shrapnel balls of the same calibre are being dealt with.

A key radiographic table is prepared by making radiographs of the bullet or shrapnel ball at the following distances from the plate: 0, 1, 2, 3, 4, 5, 6 in. (Fig. 14.)

The diameter of the bullet or ball casts a shadow the width of which is proportional to its distance from the plate, no matter at what angle the missile may be lying. The length of the bullet forms no guide.

A measurement of the uniformly cylindrical portion of the bullet is made with a fine pair of dividers; the latter are then transferred to the key plate and compared with the shadows; the shadow which they fit exactly, decides the depth of the bullet. The same method applies to the shrapnel ball, provided it is not more than very slightly deformed.

ANATOMICAL LOCALIZATION OF A METALLIC FOREIGN BODY AND RECONSTRUCTION OF ITS TRACK.

Captain Crymble²⁴ has shown the practical possibility of combining radiographic results with the information which can be obtained from a study of sectional anatomy. By this combination the actual anatomical position of a foreign body can be determined in addition to its depth from the surface or relation to neighbouring bony points. To attain this object he has employed a series of original coronal and horizontal sections of the body, and also the atlas of cross section anatomy of Eycleshymer and Shoemaker. By marking the vertical and lateral positions of the foreign body on a reconstruction of the part of the body concerned, obtained by replacing the sections in position, the sections corresponding to the position of the missile and the track leading thereto are selected.

Application of the depth measurement from the surface, or observation of the relation of the bone to the surface of the section of the body actually occupied by the missile, then allows the definite anatomical structure enclosing the foreign body to be determined.

The structures involved throughout the entire length of the track may also be worked out by the employment of a reconstruction viewed from the anterior aspect, and another viewed from the lateral aspect. On these the positions of the entry wound and of the foreign body are marked respectively. If no bone lesion is present the positions of the entry wound and of the foreign body are connected by a straight line. Where a bone lesion is present the line is carried from the wound to the bone lesion by a straight line, and from this point a second straight line connects the position of the bone lesion with that of the foreign body. Reference to the anterior reconstruction will then give the lateral position of the track in any section, and reference to the lateral reconstruction will give the sagittal or antero-posterior position in any section.

Crymble points out that the method is seldom needed in dealing with the limbs, but it is more useful in regions like the hip or the great body cavities. Further, anatomical localization both of the track and the missile is of extreme importance in prognosis and treatment in injuries to the head, and also affords a valuable means of studying the functions of the brain.

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ON SOME ANAEROBES FOUND IN WOUNDS AND THEIR MODE OF ACTION IN THE TISSUES.

BY

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THE literature on the anaerobes is beset with so many contradictory statements that it is impossible to construct from it an accurate account of the reactions of even the better known organisms. Experience has shown that this confusion is due almost entirely to the investigation of impure cultures, for, with the establishment of a more exact and rigorous technique, the features of individual species are found to become more clearly defined, and previously existing discrepancies tend to disappear altogether.

A CLASSIFICATION OF ANAEROBES.

All the anaerobes isolated from wounds are probably faecal in origin. They give vigorous fermentation reactions in the presence of organic material, and according to their biochemical activities they may be divided into two main groups—the saccharolytic group and the proteolytic group.

I. The Saccharolytic Group.

The members of this group vigorously decompose a variety of carbohydrates with the production of acid and gas, but they are only feebly proteolytic. The group comprises:

1. *B. welchii*. (Synonyms: *D. aerogenes capsulatus* of Welch and Nuttall; ¹ *B. perfringens* of Veillon and Zuber; ² *B. phlegmonis emphysematosae* of Fraenkel.³)
2. *B. tertius*. (Synonyms: *Bacillus* Y of Fleming; ⁴ *B. von Hübner* IX or *B. rodella* III of Robertson.⁵)
3. *B. fallax* of Weinberg.⁶
4. *B. aerofetidus* of Weinberg.⁷
5. *B. oedematiens* of Weinberg.⁸

Pasteur's *Vibrion septique* would seem to belong to this group, but it is omitted because we have had as yet no opportunity of establishing its characteristics.

The sugar reactions which have been found to hold good after a long series of observations are given in the following